Report NAVTRAEQUIPCEN 80-C-0095-1

TEAM TRAINING THROUGH COMMUNICATIONS CONTROL FINAL REPORT

Wilmon Crowe, Mary Hicklin,
Michael Kelly, Richard
Obermayer, William Satzer
Vreuls Research Corporation
86 Long Court, Suite C
Thousand Oaks, California 91360
and
Logicon, Inc.
Tactical & Training Systems Division
Post Office Box 80158
San Diego, California 92138

February 1982

Final Report 4 August 1980 - 4 November 1981

DoD Distribution Statement

Approved for public release;
distribution unlimited.

NAVAL TRAINING EQUIPMENT CENTER
ORLANDO FLORIDA 32813

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NAVTRAEQUIPCEN 80-C-0095-1	2. GOVT ACCESSION NO.: A118 504
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): TEAM TRAINING THROUGH COMMUNICATIONS CONTROL FINAL REPORT	5. TYPE OF REPORT & PERIOD COVERED: Final Report 4 AUG 1980 - 4 NOV 1981
	6. PERFORMING ORG. REPORT NUMBER: NAVTRAEQUIPCEN 80-C-0095-1
7. AUTHOR(s): Wilmon Crowe, Mary Hicklin, Michael Kelly, Richard Obermayer, William Satzer	8. CONTRACT OR GRANT NUMBER(s): N61339-80-C-0095
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Vreuls Research Corporation, 86 Long Court, Suite C, Thousand Oaks, California 91360	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 0781-1P1-A
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Training Equipment Center, Orlando, Florida 32813	12. REPORT DATE: February 1982
	13. NUMBER OF PAGES: 284
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

(9. Performing Organization, continued)
and
Logicon, Inc., Tactical and Training Systems Division
Post Office Box 80158, San Diego, California 92138

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Anti-Submarine Warfare	Communications Analysis
Automated Adaptive Training	Knowledge-Based Simulation
Automated Performance Measurement	Team Communications
Automated Speech Understanding and Generation	Team Training
Combat Information Center	continued on reverse

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report documents the results of an analysis of the team training problem in an anti-submarine warfare context. Based on this analysis, a system concept for a Team Training Through Communications Control Training/Research Demonstration System is presented. System functional requirements are described, and a staged implementation plan is recommended.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

Block 19, continued

Team Training Research Issues
Team Training Technological Issues

Accession For
NTIS GRA&I
DTIC TAB
Unannounced
Justification

Distribution/
Availability Codes
Avail and/or
Special
A-1

DTIC COPY INSPECTED 2

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

SUMMARY

PROBLEM

The current training of CIC (Combat Information Center) teams is costly and often inefficient and unsatisfying. A large number of interacting team members must be present, costly equipment is involved, and a high ratio of instructors to trainees is required. Existing training system designs are inadequate to handle a training situation where a team must interact mainly through voice communication while pursuing its goal in an unstructured and unpredictable environment. The area is ripe for the application of emerging advanced technologies.

PURPOSE

The purpose of this study is to develop a preliminary system concept for a stand-alone team training demonstration system which will support research into team training issues. A significant part of this development has involved extensive front-end analysis to comprehend the scope of the team training problem. Major design emphases have included the combined application of adaptive training, automated performance measurement, and automated speech recognition and speech synthesis.

APPROACH

To get to the root of team training issues, extensive analyses of several relevant facets of team training were carried out. These investigations focused on current team training, the operational environment in which teams perform, team training research issues, potential training approaches, team communications, and performance measurement for teams. A three member Anti-Submarine Warfare (ASW) team aboard a shipboard CIC provided a concrete basis for the analyses; however, it appears that this selection results in little loss of generality and that the results are applicable to many different kinds of military teams. In particular, the analyses are relevant to other CIC teams.

The system concept which emerged from these analyses calls for computer simulation of several members of the full ASW team with automated speech recognition and speech generation providing communication with the simulated supporting personnel. Most significantly, the system concept provides for the team training system to function with one or two of the human team members absent; the role of the missing team members would be played by sophisticated knowledge-based computer models.

FINDINGS

This report presents the results of an extensive analysis of the team training problem in an ASW context. Based on this analysis, a system concept was developed to support the design of a team training demonstration system.

A functional description of this system was prepared, and a staged implementation plan was put together. It is believed that the system as described is feasible, and that there is a strong need for the kind of tool it will provide. It is recommended the system be developed according to the staged implementation plan which is presented. Some short term actions are recommended. These include: (1) careful monitoring and continuing development of automated speech technologies, (2) early development of a knowledge-based system prototype, and (3) enhancement of existing training by re-emphasizing communications in the current training syllabi.

TABLE OF CONTENTS

TABLE OF CONTENTS, CONT.

TABLE OF CONTENTS, CONT.

TABLE OF CONTENTS, CONT.

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS, CONT.

LIST OF ILLUSTRATIONS, CONT.

LIST OF TABLES

LIST OF TABLES, CONT.

LIST OF TABLES, CONT.

SECTION I

INTRODUCTION

PROBLEM

Tactical decision and control in Navy Combat Information Centers require the operators to communicate with each other and with external personnel. While some communication takes place through the Naval Tactical Data System (NTDS), most team communications are verbal. Since these communications represent most of the team interaction, it is understandable that team performance, and therefore mission performance, depends on the quality of these communications. An analysis of CIC communications (see Appendix [illegible]) shows that informative and timely communications are essential to good team behavior and mission success, while lack of good communication is likely to lead to mission failure.

The training of CIC teams requires a large number of interacting team members to be present, involves costly equipment, and demands a high ratio of instructors to trainees. It is a costly and, unfortunately, often inefficient operation, since, for example, the least skilled team members can prolong training for everyone. Team training, in spite of the name, does not usually involve formal training in team skills. Because of insufficient or inappropriate communications, the trainees often simply do not perform as a team for much of initial training.

Clearly, team training is worthy of the application of advanced technologies and of research into improved team training techniques. However, existing training systems, or training research systems, do not provide for automation with multiple trainees interacting mainly through speech. One cannot hope to develop automated training techniques applicable to CIC team training without having an automated speech understanding capability. Nor can one advance team training methods through research in critical areas such as team characteristics, communications, feedback, training sequence, task environment, and performance measurement with more traditional techniques. Application and extension of the emerging advanced technologies is very much in order.

PURPOSE

The purpose of the current study is to perform front-end analyses for preliminary design and determination of feasibility of a stand-alone research training device. Major design emphases are the combined application of adaptive training, automated performance measurement, and computer voice synthesis and recognition.

APPROACH

The front-end analyses included:

- current team training
- operational environment
- team training research issues
- training approach
- team communications
- models of operator behavior
- performance measurement
- hardware and software requirements

While it is intended to extend the application of emerging technologies to a variety of military teams, these front-end analyses require the analyst to get very specific if the end result is to be useful. For this reason, a specific application--the Anti-Submarine Warfare (ASW) team in a shipboard CIC--was selected. However, it is believed that this selection results in little loss of generality, especially to other teams in the CIC (see Appendix K).

More specifically, the ASW team of a DD-963 (Spruance class destroyer) is assumed for analytic purposes. It is assumed that at most three members are physically present for training; these are the ASW Operations Coordinator (ASWOC), the Anti-Submarine Air Controller (ASAC), and the ASW Fire Control Officer (ASWFCO). All the other ASW team members are simulated using computer models of their behavior which employ automated speech recognition and speech generation. Furthermore, each of the three team members may also be modeled, so that at the extreme, team training may be attempted with only one trainee.

The design orientation calls for all models to perform at a high level of competency, and, therefore, the model-ASWOC (for example) may be compared to the trainee-ASWOC. Provision for lesser levels of model performance is required to permit future training with deteriorated team performance. Of course, simulator functions (such as vehicle motion, support personnel, and performance measurement) must be activated by speech recognition when other user inputs cannot be used. (A more detailed description of the system concept is presented in Section IV.)

BACKGROUND

In the past, the emerging technologies have been employed in the attempt to improve flight training and ground controller training systems, but it is expected that the approach can be extended to military team training systems. The development of these subsystems is charted by a series of Navy training programs (see Appendix A):

- Tactical Advanced Combat Directions and Electronic Warfare (TACDEW) (involves simulation, replay, very simple performance measurement);
- Adaptive Flight Training System (AFTS) (involves simulation, replay, performance measurement, simple feedback, simple adaptive logic);
- Ground Controlled Approach - Controller Training System (GCA-CTS) (involves simulation, replay, performance measurement, feedback, adaptive logic, simple computer aided instruction, simple diagnosis and remediation);
- Air Controller Exerciser (ACE) (involves extensions of all the foregoing).

In terms of previous system designs, then, what is different about the current program? One difference is that the "trainee" is a "team," and that communications is a focal issue. A particularly important and basic difference, which will significantly affect the design, is that the military team situation is rather unspecific and unpredictable compared to previous applications. We are therefore challenged to push the state of the training technology to provide solutions which heretofore have not been available: the design of automated training as applied to team performance, focusing on communications control, and in a dynamic (CIC) environment.

FOCUS OF THIS REPORT

The main body of this report discusses general aspects of the team training system. This discussion begins with the analysis of team training presented in Section II and continues with a discussion of the theoretical research issues in Section III. Section IV describes the system concept at a general level, and Section V discusses some of the technological research issues involved in the implementation. Section VI provides system functional requirements, while Section VII provides a suggested implementation plan. The report concludes with conclusions and recommendations in Section VIII.

The body of the report is immediately followed, as required, by the list of references. This organization is a bit awkward, since most of the references to the literature occur in the more technical appendices. It was considered advisable, nonetheless, to consolidate all references here, rather than provide separate reference lists for the appendices.

The bulk of technical detail has been relegated to the appendices, two of which have been published separately because of their confidential classification. Appendix A discusses training technology. Appendix B provides a comprehensive review of the literature on team training. Appendix C (separately bound) provides a scenario for the envisioned team training system. Appendix D provides a graphic representation of the high level knowledge of one team member (the ASWOC). Appendix E describes the functional characteristics of the training consoles. Appendix F lists the communications circuits used by the team members. Appendix G provides the automated speech technology requirements. Appendix H describes software design considerations, while Appendix I offers a more detailed design for the knowledge-based models recommended for the system. Appendix J provides a most interesting analysis of the communications used in three tape-recorded training sessions. Appendix K offers a description of the generic aspects of Anti-Air Warfare (AAW) training which suggest that the concepts developed here may be applicable to a broad range of military training situations. Appendix L, also separately bound, provides the evaluation sheets presently used in evaluating team training to show the emphasis placed upon good communications. A Glossary of terms and acronyms concludes the report.

SECTION II

TRAINING ANALYSIS

A training analysis was conducted for ASW Team Training and is presented in three parts: (1) observations of fleet team training, (2) task analysis, and (3) performance measurement analysis.

OBSERVATIONS OF TEAM TRAINING

It had been initially intended to collect training and task data for DD-963 and FFG-7 class ships. However, training personnel convinced us that a compatible analysis was not possible between the two ships, and furthermore, the DD-963 presented a better ASW subject.

Consequently, observations of team training were limited to the DD-963. ASW training was observed in two DD-963 ships dockside, multi-threat exercises at the Fleet Combat Training Center, Atlantic, and training sessions at the Fleet Combat Training Center, Pacific. One of the dockside sessions was conducted primarily for diagnostic purposes to prescribe needed classroom training, and the multi-threat exercise did not include ASW (although the team training was highly analogous and informative). Therefore, the following discussion will emphasize the specific information collected from one three-day dockside training exercise and one three-day simulator training exercise. To avoid redundant descriptions, the presentation will center on the dockside training, and occasional references will be made to the simulator training where additional details should be noted.

TRAINING PROCEDURE. Dockside training was conducted in the ship's Combat Information Center, using the ship's computer and all normal work stations. Special training software was loaded into the computer to permit the conduct of training exercises as specified by the instructional team. Eight instructors from the Fleet Anti-Submarine Warfare Training Center, Pacific, conducted the training. All except the training supervisor manned stations to perform the functions of helicopter pilots, Scene of Action Commander, sister ship, submarine maneuvering, and the like. Ship maneuvering commands were transmitted to the bridge where course changes were entered manually to cause heading and speed instruments to indicate properly.

The Operations Summary Console (OSC) was not functioning throughout the training exercises, so these functions were performed manually on the Dead Reckoning Tracer. The team under training included the Anti-Submarine Warfare Operations Coordinator, North and South Plotters, R/T (Radio/Telephone) Talker, Anti-Submarine Air Controller, Anti-Submarine Warfare Fire Control Officer, Surface Tracker, and Sonar Operators (in an adjacent room).

As the computer was not functioning properly at first, a lecture was delivered at the outset; however, this lecture would have been delivered at some point. The lecture included a "walk-through" of an ASW exercise,

highlighting critical definitions and procedures, reviewing appropriate tactics, providing specific recommendations for tactics during the exercises to come, and identifying specific dos and don'ts. No specific instruction was given with regard to team interaction, except to generally encourage team members to talk to each other for better understanding of their interdependency.

Information was given over the loudspeaker with regard to the problem setup prior to starting the simulation. This information included ship's heading and speed, the mainbody unit being escorted intelligence about possible submarine encounters, sonar conditions, and helicopters and weapons under control.

Each exercise was conducted largely without instructor intervention, although the instructors could modify the training problem and direct the problem if the trainees were having trouble. Note that subtle instructor interaction was possible: for example, the ASAC was talking to a simulated helicopter pilot who was, in fact, an instructor-ASAC.

A debriefing session followed each exercise. The primary debriefing was held by the training supervisor at the Dead Reckoning Tracer (DRT). His comments were directed primarily to the ASWOC, the plotters and the R/T talker, and others were called to the table as required. The ASWFCO and ASAC may have had some interaction with their instructor counterparts after an exercise, but this was not apparent.

Exercises were planned for a three-day period. The exercises proceeded through the following sequence (interestingly, adding assets increased problem difficulty):

1. ownship

2. ownship + LAMPS helicopter

3. dual ship

4. ownship + LAMPS helicopter + dipping helicopter

5. dual ship + LAMPS helicopter + dipping helicopter

These exercises were often repeated, but ordinarily this was because of team member substitutions. There were two ASWOCs, two ASACs, and several R/T Talkers being trained. All of the team members had other duties to perform on ship, and the composition of crews changed with each exercise.

Task difficulty was changed in other ways: difficulty changed with types and quantities of weapons available, position and type of submarine, and restrictions upon escorting and maneuvering of the mainbody units. For example, the DD-963 might be required to maintain station near the mainbody, and might not be allowed to significantly maneuver the mainbody out of trouble.

Simulator training was administered in the following similar sequence:

1. Target Maneuvering Analysis (TMA) Basics
2. Sonar Mockup Familiarization (Sonar Technicians (ST) only)
3. Surface Attack Unit (SAU) Procedures
4. LAMPS
5. Mockup Familiarization
6. Passive Target Maneuvering Analysis
7. Single Ship ASW
8. SAU/Mainbody Operations
9. SAU/LAMPS Operations
10. SAU/Mainbody/Multi-Aircraft Operations

It is understood, however, that the two sessions dealing with Target Maneuvering Analysis have been subsequently deleted from the simulator schedule. Passive techniques were emphasized to a greater extent with the simulator than with the dockside training.

RESULTS. At the beginning, even with limited assets to control and with a submarine traveling in a straight line, the situation was chaotic. However, by the end of the three-day session, the ASW team performance was reasonably good, even with a complex setup (note, however, maneuvering of the adversary submarine was always limited). In short, learning seemed to take place.

The items in Table 1 are errors gleaned from the debriefings following each exercise; they show the types of difficulties as emphasized by the instructors. Note that the emphasis is on tactical errors, safety, time efficiency, and routine procedures; there was virtually no feedback on team behavior. There was some reinforcement of desirable performance, but feedback was primarily negative.

Informal debriefing in the observed simulator exercises was quite similar to that in the dockside training. Little direct emphasis was placed on team communications, except that in one case debriefing did make a strong issue of ASWOC-ASAC communications which had been almost totally absent. Also, it is clear from the formal evaluation sheets used in the simulator training (reproduced in Appendix L), that team communications are strongly emphasized and specifically evaluated.

TABLE 1. DEBRIEFING COMMENTS.

ASAC--didn't announce that the helicopter was out of the weapon danger area (held up by prosecution of attack).

ASWOC--during an urgent attack, used a torpedo instead of a weapon that could get there quicker.

ASWOC--didn't upgrade the classification of the submarine, affecting the possibility of weapons free for attack.

ASWOC--didn't make correct turn and endangered ship.

ASAC--should have directed helicopter down track of submarine.

ASAC--could have prosecuted urgent attack quicker with the helicopter.

ASAC--ordered helicopter to drop weapon, but did it without proper preliminary communication, so that the helicopter balked.

ASWOC--turned parallel to submarine track (good).

Plotter--incorrectly computed Estimated Time of Arrival (ETA).

Plotter--confused magnetic bearing with true bearing.

Talker--confusion as to when to use yards or miles.

ASWOC--made ineffective use of assist ship.

ASWOC--didn't turn mainbody out of danger.

ASWOC--brought helicopter back prematurely with weapon unexpended.

Plotter--didn't plot dipping helicopter.

ASWOC--got ownship out of position.

Plotter--delayed in plotting possible submarine courses.

Talker--said "port" instead of "starboard," used wrong code name for weapon, required excessive direction (new man).

ASWOC/Plotter--new range of predicted courses not plotted when the submarine turned toward the mainbody.

Informal discussion with training personnel indicated some unhappiness with the shipboard training procedure. Equipment seldom worked properly in the training mode, and much equipment was down routinely. Furthermore, on the ship the duties of the crew did not cease for training, preventing continuity of training with an intact team. Also, the visiting instructors felt somewhat awkward in their training role, for there were highly qualified personnel onboard who were, in their opinion, capable of giving the training (e.g., the CIC supervisor was an experienced chief). Finally, although time is normally allocated for ship training on a daily basis, it often had to be used for the accomplishment of other ship duties.

TASK ANALYSIS

MISSION DESCRIPTION. A description of the operational environment is given in Appendix C, but the following description is given to provide a background for the ASW team tasks. This description is intended to provide a setting for the subsequent analysis of these team tasks.

The ASW ships will normally be escorting a mainbody of other ships, probably including an aircraft carrier. The close escort function will continue until the presence of an underwater threat is discovered or suspected. At this time a datum is established--a position at a given time given along with a probable error. However, the submarine can continue to move at rates up to its maximum speed in any direction from the datum. Therefore, a circle is plotted centered on the datum which represents an area containing the submarine. This circle must be replotted periodically with a larger radius.

The ASW team can also make the assumption that the threat, if real, will attempt to make an intercept with the mainbody. The possible approaches to the mainbody can be estimated given some assumptions about the minimum and maximum speed of the submarine threat. Given this type of analysis, the team can make some informed statements about the probable location of the submarine over time (i.e., within an expanding circle and possible intercept paths), and make some intelligent decisions with regard to methods of searching for and intercepting the threat.

A Search and Attack Unit will be formed to engage the threat under the command of the Scene of Action Commander (SAC), probably the SAU Commander. The ships, thus detached, will proceed in formation to intercept the threat; the formation, line of approach, and speed are decisions to be made considering the nearness of the threat, the available assets, and the characteristics of the ship's sonar equipment.

A characteristic of ASW missions is that sonar or visual contact with the threat is infrequent and intermittent. The ASW team must always have a plan ready for search and another for attack: these must be determined in advance and must be communicated to the entire ASW force. These plans are selected from published tactics, and the selection is ordinarily made

from a small set of likely candidates. The plans will make clear to the SAU the conditions under which each ship should take action and are designed to avoid mutual interference.

If air assets, such as helicopters, are detached with the SAU, these units can act as long-distance, high-speed arms for search and attack. Again, published tactics are available for selection of both search and attack. Often the use of the helicopter units for search will involve laying down a complex pattern of sonar units. Also, helicopter detection may come before the ships can arrive on the scene and, therefore, may also be used to deliver a weapon.

The ships may continue to approach the threat, unless helicopter action occurs first, or unless the SAU is required to stay close to the mainbody. If the ships arrive within the range of enemy weapons, they must maneuver evasively to prevent the submarine from obtaining a fire control solution. Under some circumstances, the ship may attack immediately, even though the probability of kill is low; otherwise, the ship will select a weapon from the available arsenal and wait for a carefully calculated fire control solution.

During attack, the ASW team is responsible for keeping the assets of the SAU clear of weapon danger areas. For example, the helicopter units must be kept clear of air launched weapons, and preferably should be dispatched to a good backup position.

Note that the initiation of an attack is carefully constrained and controlled by higher-command authority. There are specific conditions established under which a "weapons free" condition is established, and the ASW team has an obligation to communicate information which will affect the classification of the threat. Under some conditions, no attack will take place, and the mission will be solely to track or "hold" the contact without closing on it.

STATE DIAGRAM. A diagram of the above conditions is presented in Figure 1. Each major activity is presented as a "state" with key decisions indicating when the transition from one state to another will occur.

A state diagram can be drawn for each asset in the SAU; a diagram is presented which can be representative of either sister ship and another which can be representative of each air asset.

These state diagrams serve to indicate the position of ASW on the established/emergent continuum, as discussed elsewhere (see Appendix B). While there are often guidelines which strongly define courses of action, there are not rigid procedures within any state.

For example, a specific approach course may be selected for a number of reasons so as to make it appear that the threat has not been detected; an attack may be prematurely launched to put the submarine on the defensive;

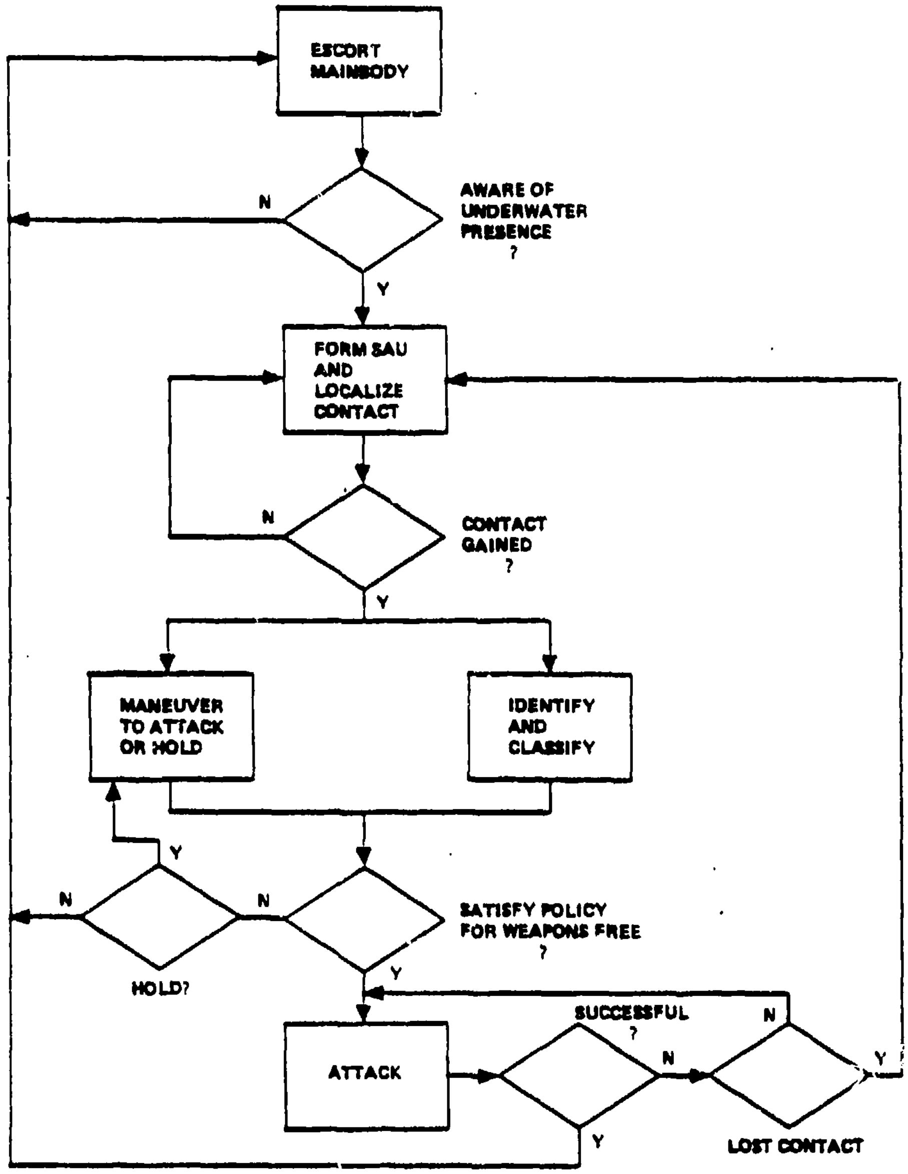


Figure 1A. State diagram (ship).

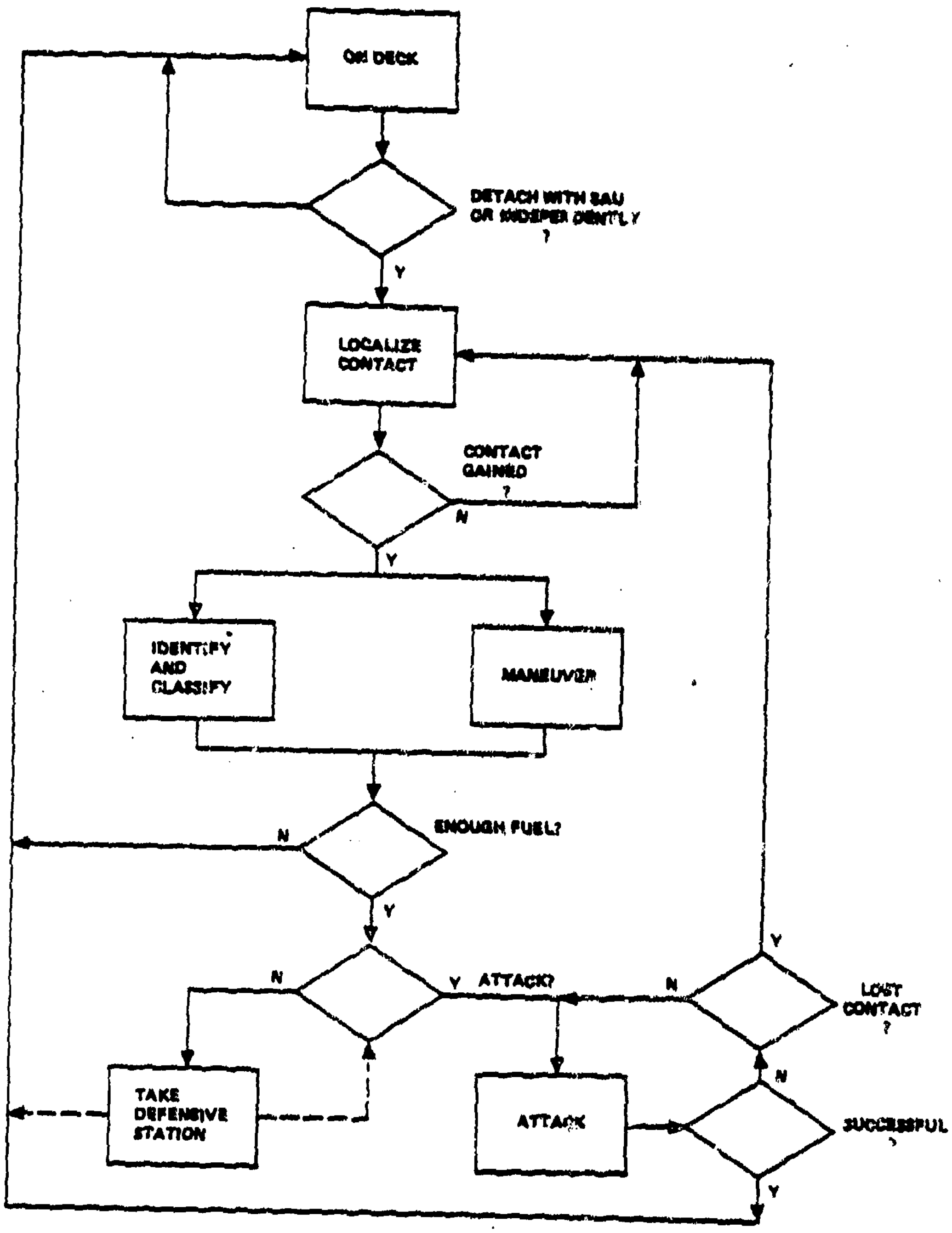


Figure 1B. State diagram (helicopter).

or the decision to attack with air assets or ship assets may depend upon the policy of the specific ship's commanding officer. In the process of localizing the threat, contact can be established, then contact can be later lost during attack, then regained and attack again commenced, etc. The other ship might get "hot" and attack ship/assist ship roles will change; the ASWOC may choose to do something unusual, like putting the submarine in the baffles (with proper notification to sonar); the ASWOC may quickly change to use of the helicopter instead of attacking with the ship or decide to use a different weapon. While the sequence of actions, and the consequences, are sometimes predictable with high probability, the situation can be classified well toward the emergent end of the continuum.

OPERATIONAL SEQUENCE DIAGRAM. In an effort to graphically display team interactions, an Operational Sequence Diagram, or OSD, (Kurke, 1961) was developed and is presented in Figure 2. This OSD presents the analysis scenario which is described elsewhere; however, the following comments are offered as an interpretative aid.

The scenario begins after an intelligence briefing and assumes that the Search and Attack Unit is already formed and the two ships are proceeding toward the datum (last estimated position of the submarine) in formation. It is further stipulated that the trainees are part of the crew of the sister ship and that the SAU Commander is on the other ship. This role is forced in order that the mission can proceed in an orderly way without perturbation by the possibly extraneous actions of trainees. Note, however, that the helicopter is under the control of the ASAC on the trainees' ship, and when the submarine is under sonar contact, full control will revert to the trainees during the attack phase.

The OSD emphasized communications, since these are the principal interactions between the team. Other interactions can also take place through NTDS consoles, which are also indicated on the OSD. NTDS console displays are not indicated generally in the OSD, and one should be aware that console actions by one team member are available for display on the consoles of the other team members.

It was desired to emphasize the flow of information throughout the team, and aiding arrows were added to the OSD for this purpose. It can be seen that a single event will often trigger a cascade of communications throughout the network.

Particularly significant actions have been identified by means of asterisks (*); the symbols used throughout the OSD are listed and are a slight modification of the symbols proposed by Kurke (1961).

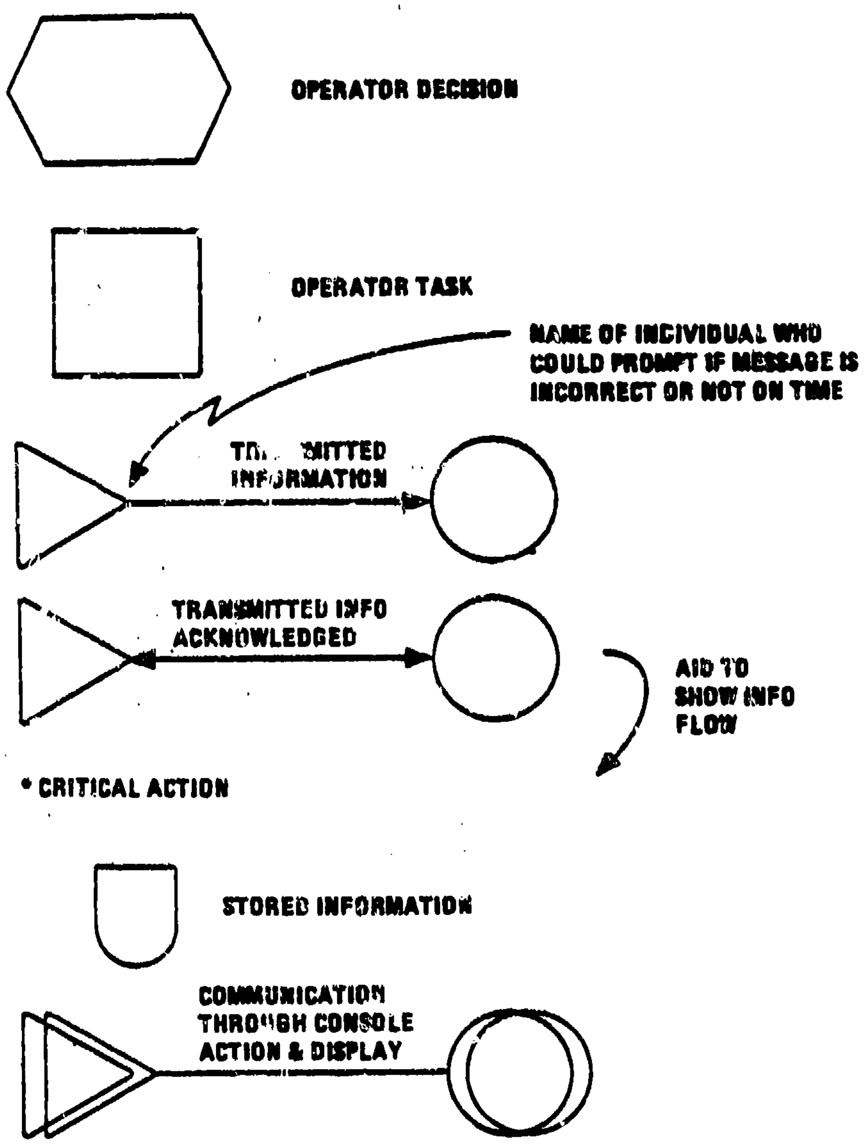


Figure 2. Operational Sequence Diagram
A. Symbols used.

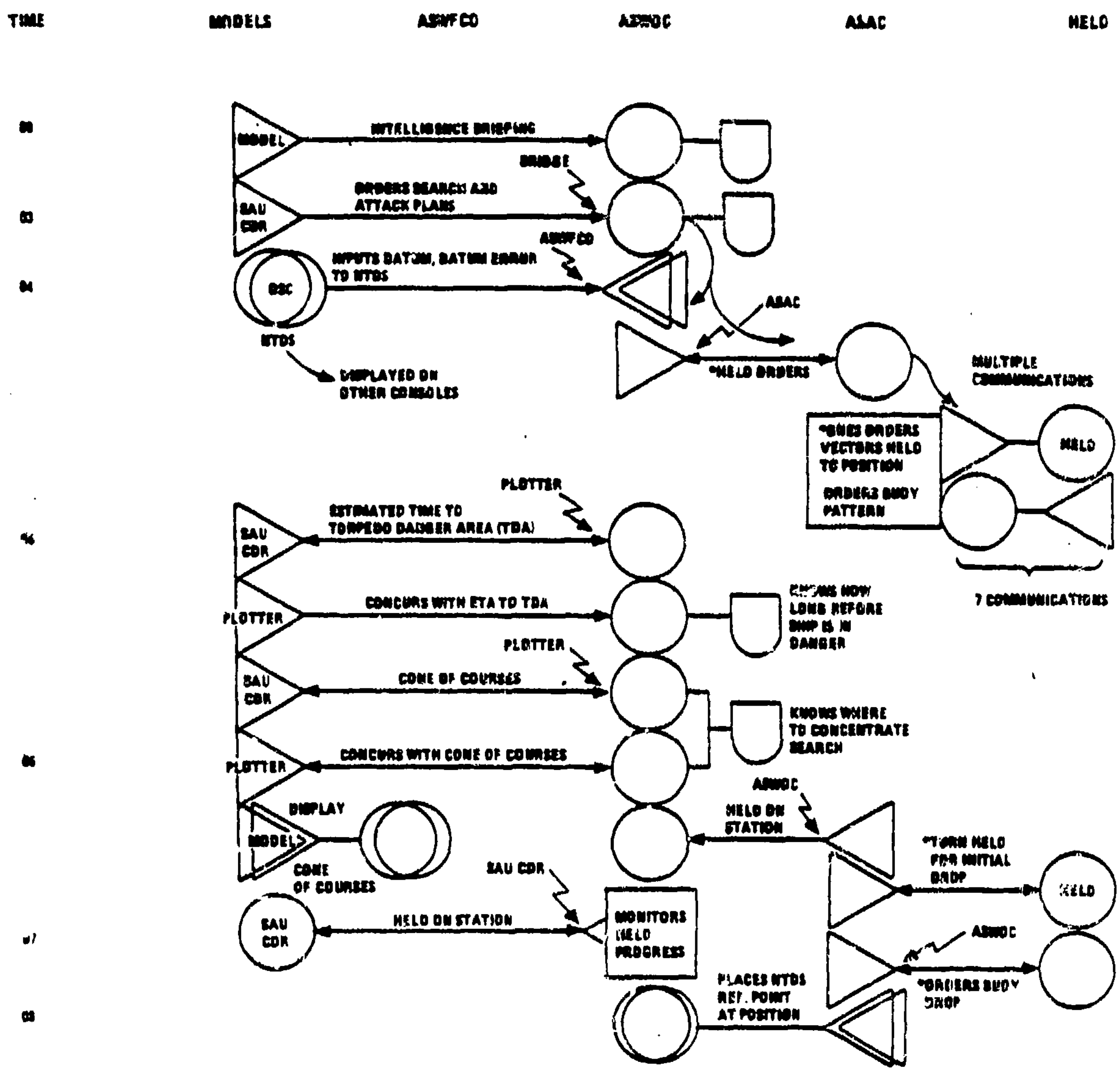


Figure 2. Operational Sequence Diagram
B. SAU formed, begin localization.

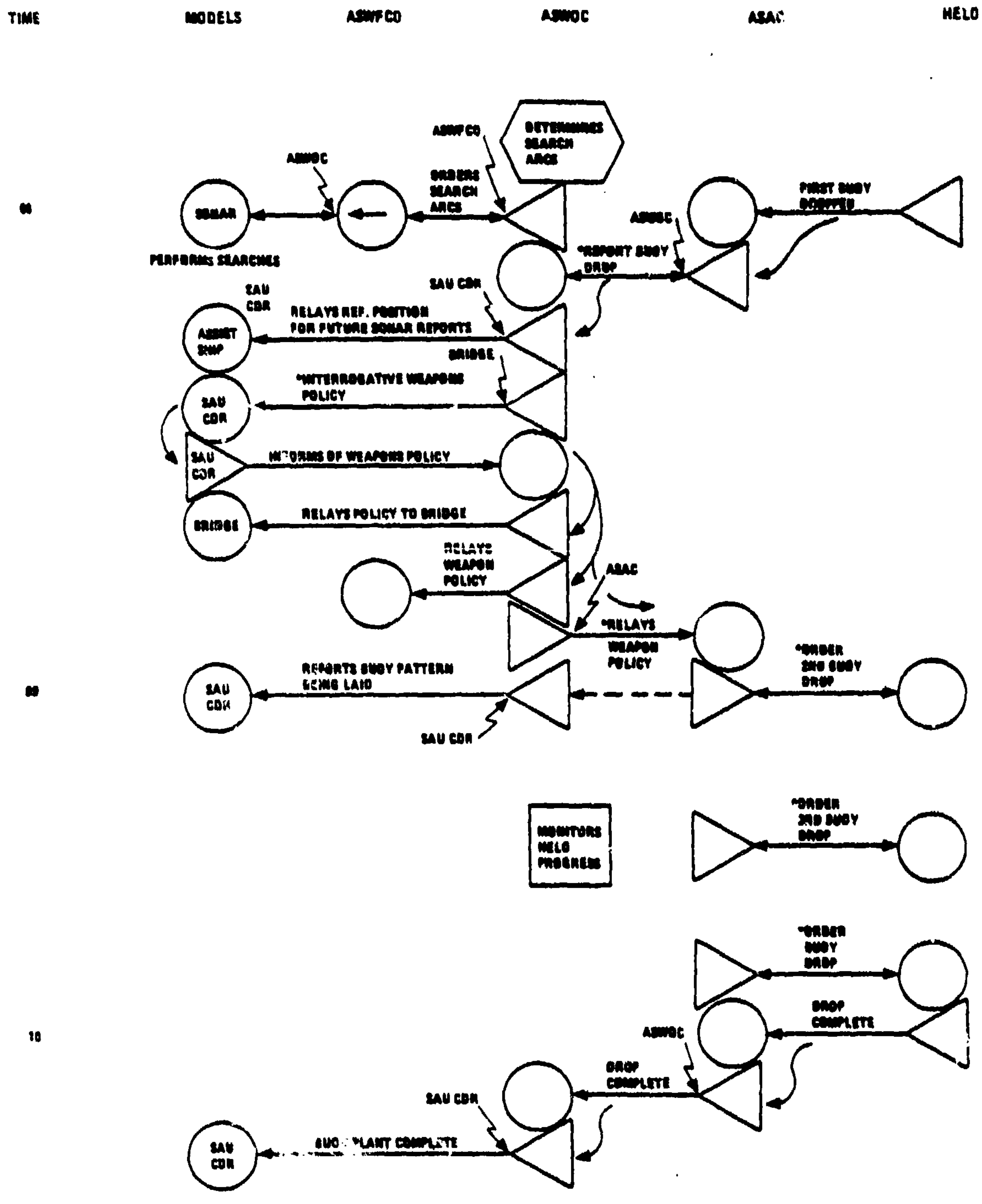


Figure 2. Operational Sequence Diagram
C. Localize contact.

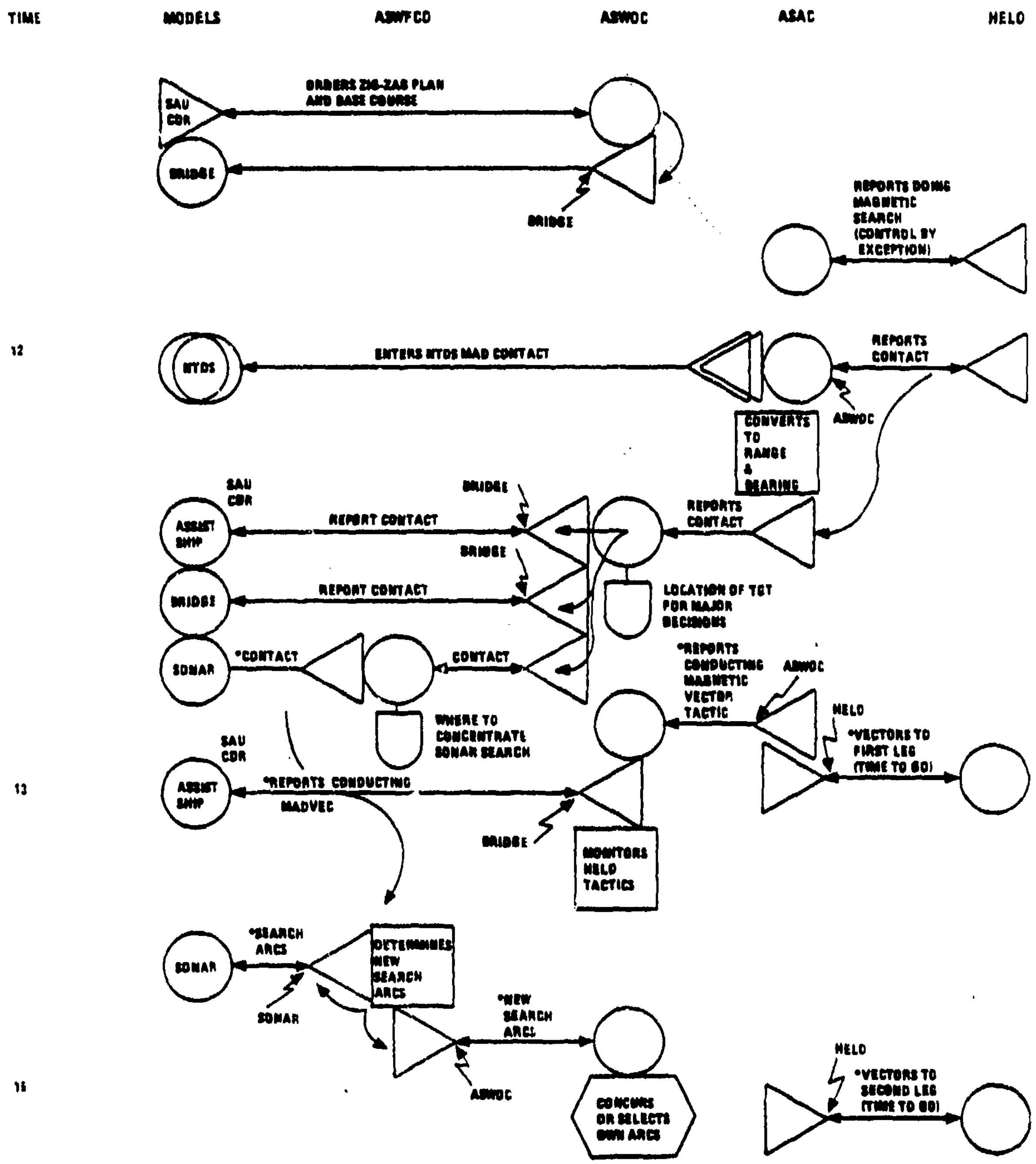


Figure 2. Operational Sequence Diagram
D. Maneuver to attack or hold.

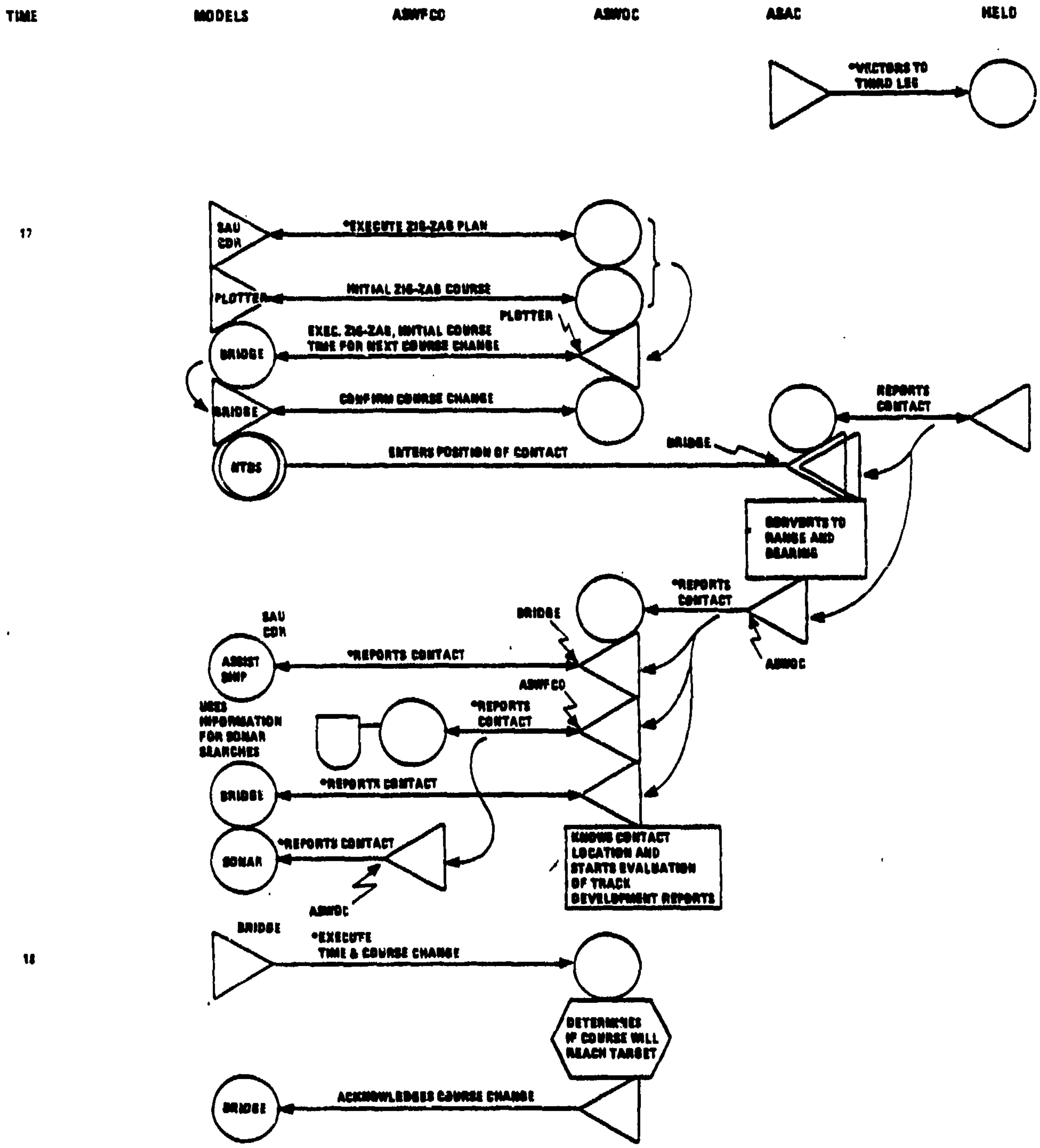


Figure 2. Operational Sequence Diagram
E. Identify and classify; maneuver to attack or hold.

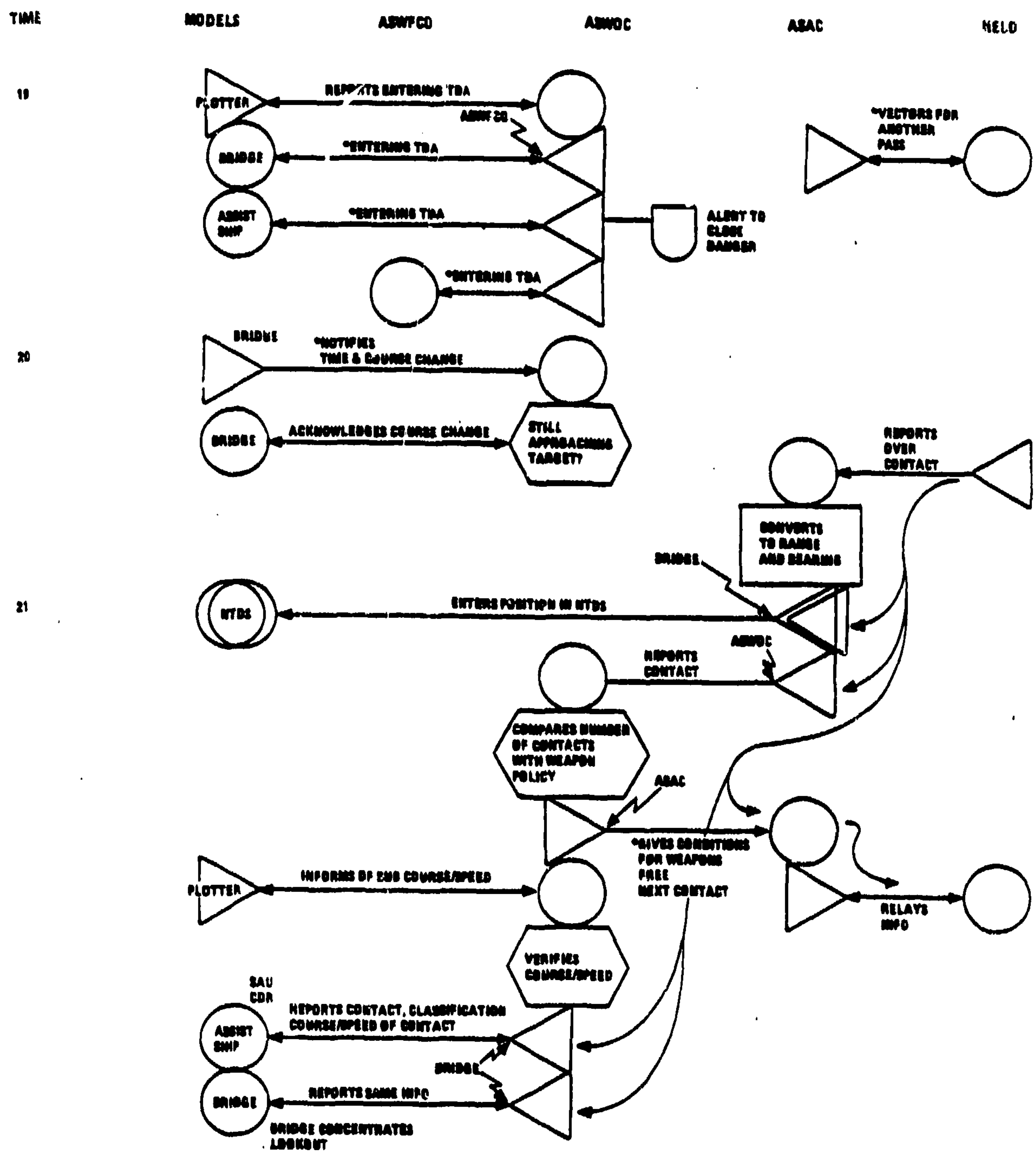


Figure 2. Operational Sequence Diagram
F. Identify and classify.

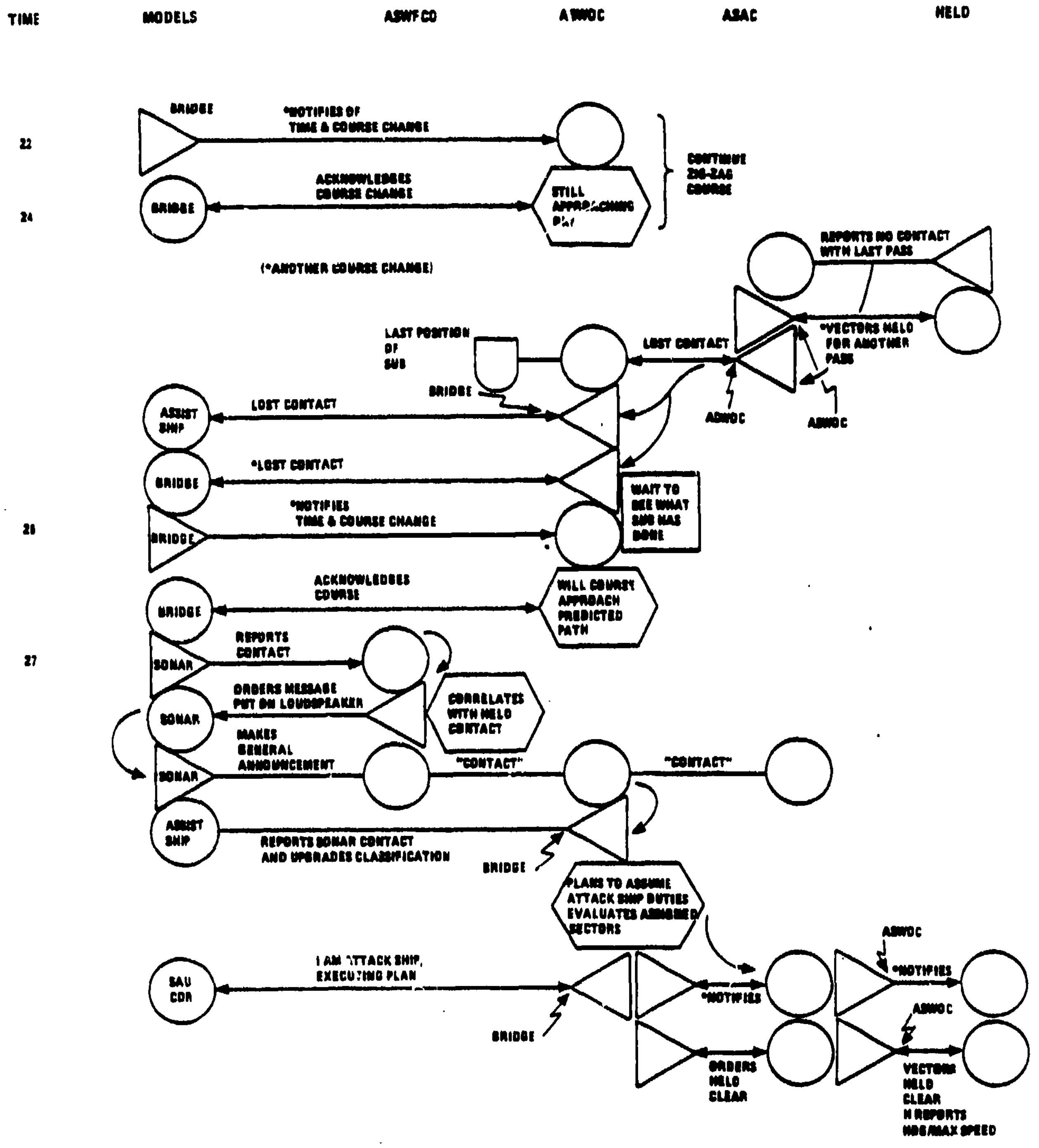


Figure 2. Operational Sequence Diagram
G. Contact lost and regained.

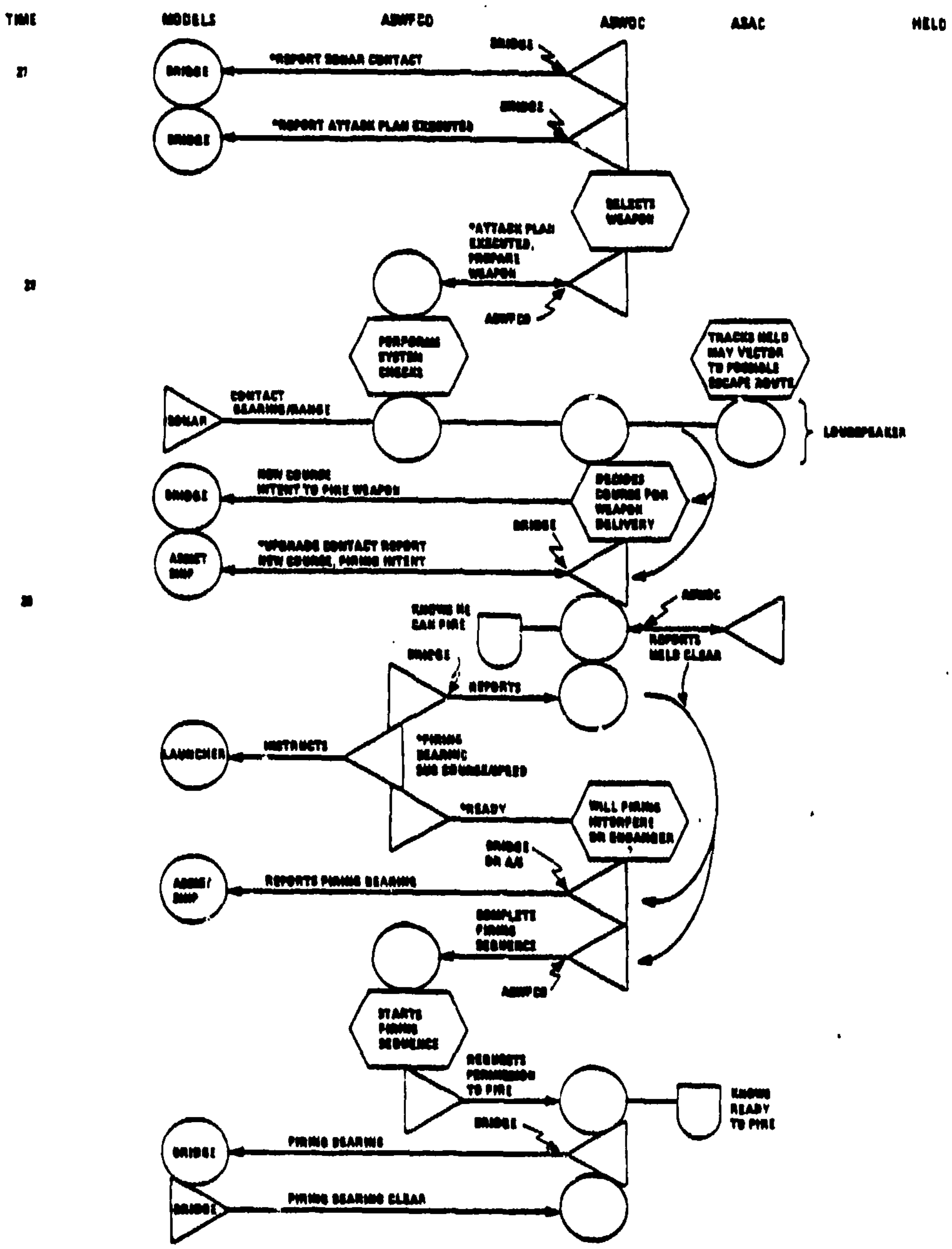


Figure 2. Operational Sequence Diagram II. Attack.

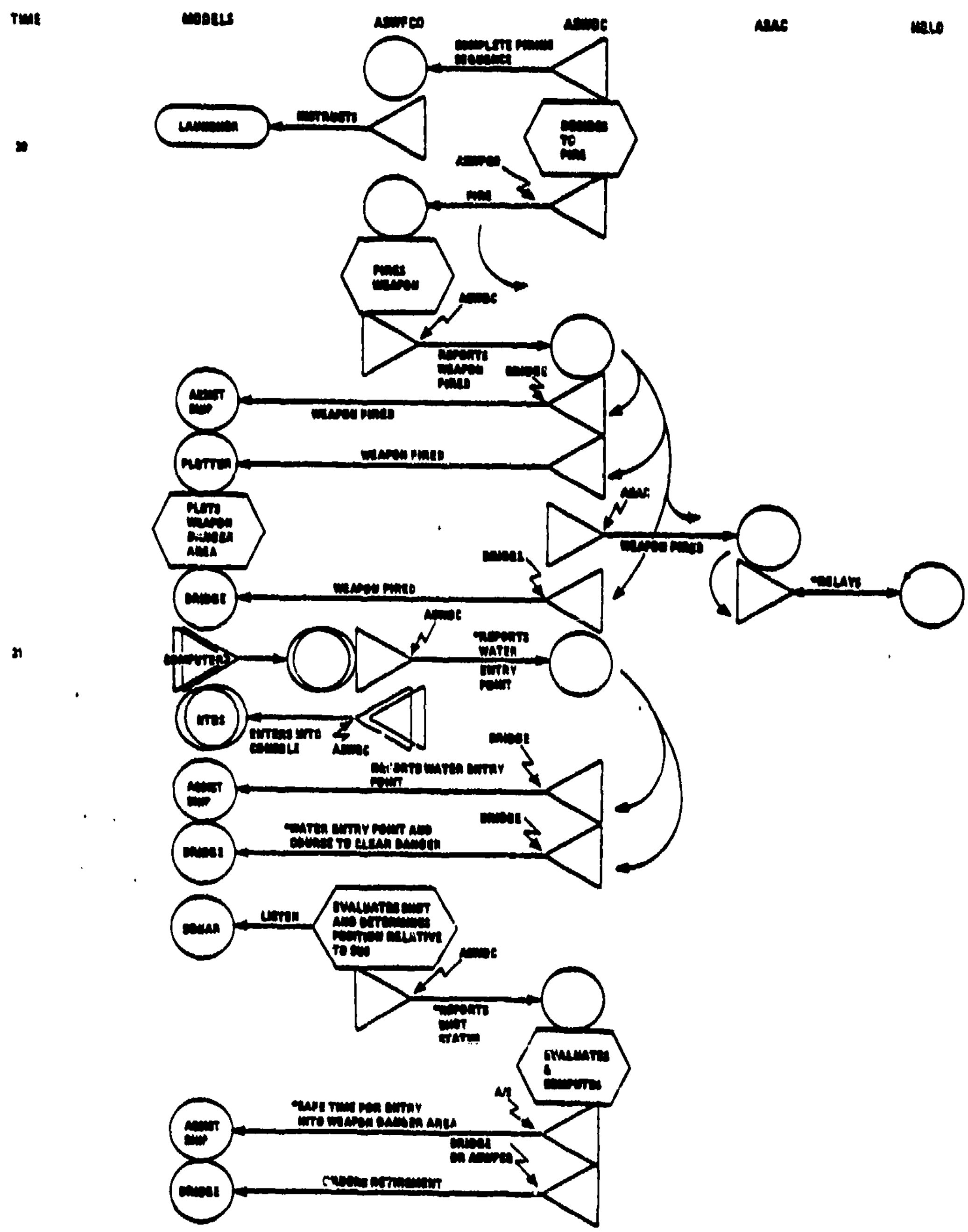


Figure 2. Operational Sequence Diagram
I. Fire and evaluate.

As part of the task analysis, most communications are marked to indicate a team member who could provide a prompting comment if a communication is omitted, delayed, or in error (zigzag arrows on the OSD). Training of team skills could include instruction for each team member to provide such backup communication assistance.

COMMUNICATION LINKAGES. Communications were counted (acknowledgements also) in the segments of the scenario and were accumulated to form a total, as shown in Figure 3. These counts, or linkages, show the communication load as it varies throughout the scenario.

As should be expected, the ASWOC communicated to the greatest number of individuals, with a consistently heavy load to the SAU Commander at the assist ship. Otherwise, the ASAC communicates most, as is necessary to control the helicopter, at least, until the helicopter is cleared out of the way to permit a direct attack from the ship. In general, the ASWFCO has the lightest communication load, however, this picks up significantly during weapon delivery.

It is particularly noteworthy that the ASAC and ASWFCO do not ordinarily communicate directly with each other. Therefore, the three team members do not form a triad, but two meshed dyads.

PERFORMANCE MEASUREMENT ANALYSIS

The Performance Measurement System (PMS) to be developed must serve three purposes: first, it must provide real-time information concerning the performance of the team and team members during an exercise in order to support the adaptive training capabilities of the device. This will include positive feedback on correct performance and mistakes or less-than optimal actions in time to allow these problems to be rectified. It will also provide data to be used by the device for determination of possible alterations in the exercise structure. This will require that correct actions and errors by the team members will be recognized as they occur.

The second purpose of the PMS is to provide data to be used during post-exercise debriefing and team evaluation. While real-time performance assessment is not necessarily required for this purpose, the performance data must be available within minutes after the conclusion of an exercise. Somewhat more comprehensive information may be needed for this purpose.

The third purpose of the PMS is to provide information for the scientist performing research on team training and team performance. This kind of performance data can be provided somewhat later than the others. To meet this purpose, a comprehensive and highly flexible performance measurement system will be required. This will probably include a requirement for an off-line data analysis capability for much of the communication data.

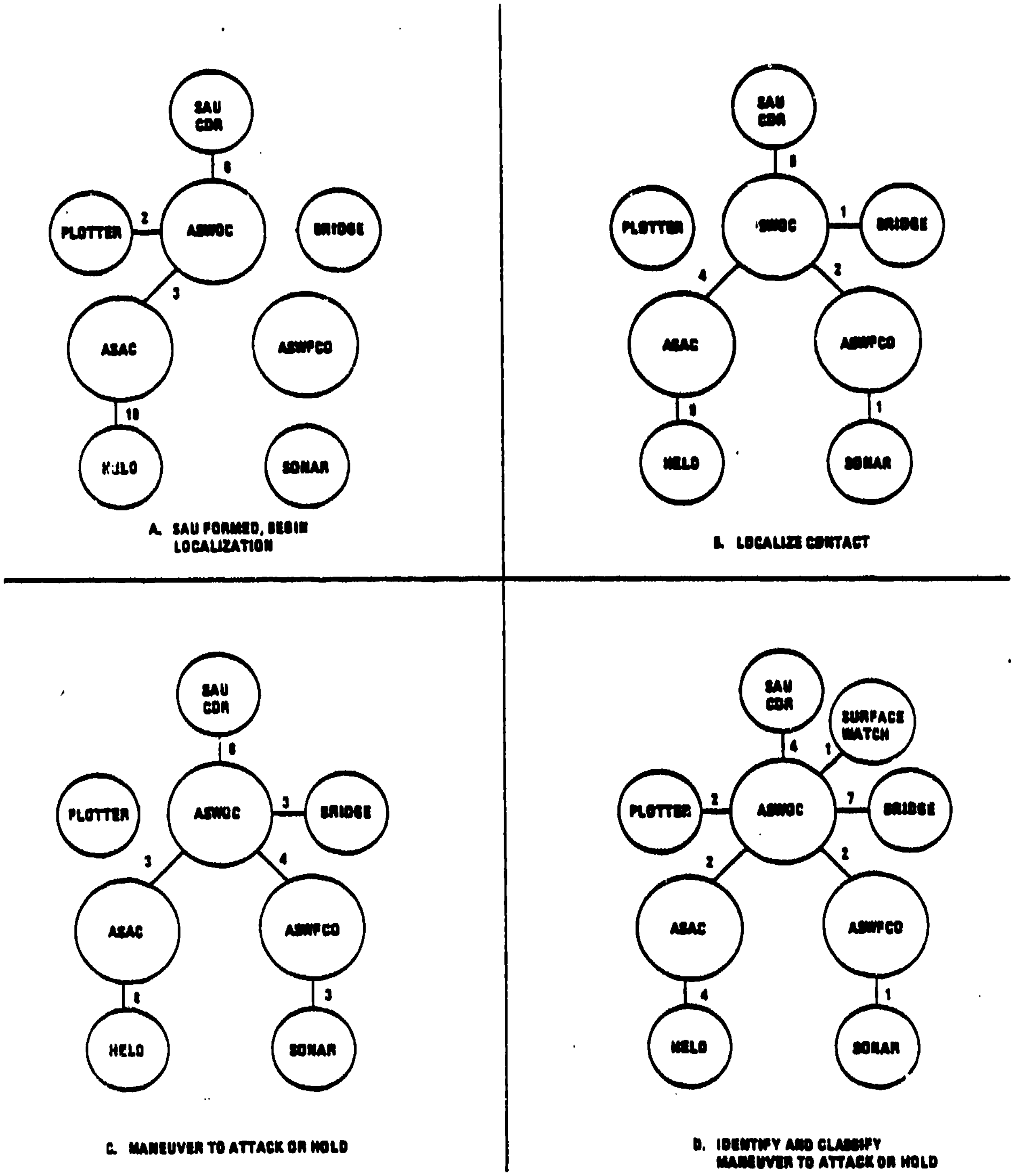


Figure 3. Communication linkages.

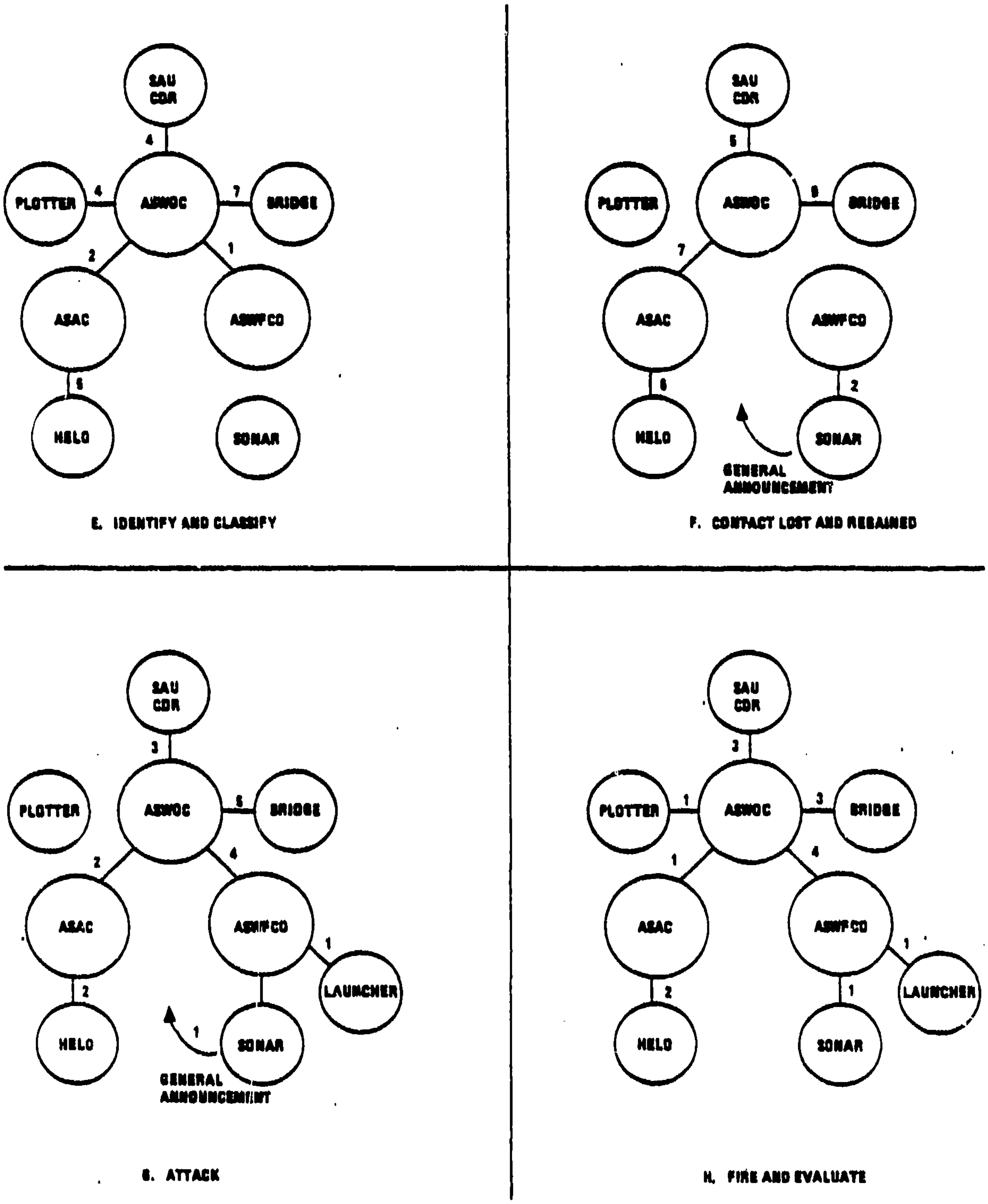
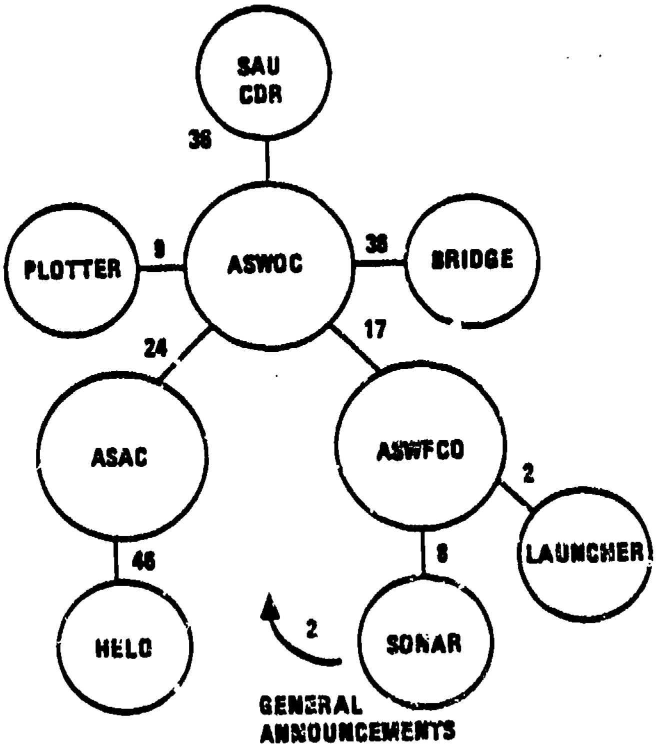


Figure 3. Communication linkages, cont.



1. TOTAL SCENARIO

Figure 3. Communication linkages, cont.

To meet these goals, the philosophy for the development of the PMS functional specification was to provide the most detailed analysis possible, given the state of the art, while providing the maximum possible flexibility. This will allow desired alterations to be made easily in support of changing training and research needs. This flexibility is critically important, especially since one of the major research issues to be addressed by the device involves the nature of the most effective performance measurement in future automated team training systems.

The three principal sources of information consulted for information leading to PMS development were: Naval ASW tactical doctrine, interviews with subject matter experts (both in-house and Navy personnel), and examinations of recommendations from past efforts. For various reasons, however, only a limited amount of directly applicable information could be gleaned from these sources. Performance assessment during current ASW training is usually subjective and at a rather global level. Although there are a few rules-of-thumb concerning, for example, the amount of time certain segments of an exercise should require, little objective measurement is used other than for checks on the accuracy of calculations and plots. Most performance assessment involves examination of decisions and tactics. Such assessments do not easily lend themselves to automated performance measurement (cf., Bell, 1978).

For these reasons, the major portion of the measurement structure for this device will use measurement which is untested for ASW tasks. However, the selected structure has proven to be effective in the aircrew training environment.

SEGMENTATION. The performance measurement uses a mission segmentation structure based on required or desired actions by the team members. Table 2 presents an analysis of the actions and communications which are important to the success of the mission for the selected scenario. These events and communications are grouped into task segments with each segment representing an individual subtask which must be completed by the ASW team. The events generally represented important (often critical) pieces of information that must be exchanged by the team members in order for that subtask to be accomplished successfully.

The start and stop conditions for each of the segments are shown in Table 3. Measurement of each segment begins when the event designated as the start event occurs. Measurement of that segment continues until the specified stop conditions have been satisfied. As each specified event within a segment takes place, a record will be made of the time into the mission at which it happened, and, where appropriate, an evaluation of the accuracy of the information contained in the communications will be recorded. For the prototype device, a count of the number of critical events completed and the number and percent of accurate communications will be used to provide performance measurement information. In addition, the number of unclosed segments will be counted and scored.

TABLE 2. MEASUREMENT SEGMENTATION BASED ON TEAM MEMBER COMMUNICATION.

TIME	SEGMENT	EVENT	COMMUNICATOR	TO	ACTION	MEASURES
03 00	1	1	Model	ASWOC	Provide intelligence briefing	None
	1	4	Model	ASWOC	Send Plan Red, Plan Black	None
03 00	1	5	ASWOC	Model	Acknowledge	A
04 00	2	1	ASWOC	ASAC	Sends helo orders	A+B
	2	2	ASAC	ASWOC	Acknowledges	A
	2	3	ASAC	Model	Takes control of helo	A
	2	4	Model	ASAC	Acknowledge	None
	2	5	ASAC	Model	Pass helo orders	A+B
	2	6	Model	ASAC	Acknowledge	None
	2	7	ASAC	Model	Vectors helo	A+B
	2	8	Model	ASAC	Pass helo speed and altitude	None
	2	9	ASAC	Model	Acknowledge	A
07 00	2	10	ASAC	ASWOC	Report helo on station	A
	2	11	ASAC	Model	Turns helo to drop axis	A+B
	2	12	Model	ASAC	Acknowledge	None
08 00	2	13	ASAC	Model	Orders buoy drop	A+C
05 00	3	1	Model	ASWOC	Send ETA to TDA	None
	3	2	ASWOC	Model	Acknowledge	A
	3	3	Model	ASWOC	Plotter concurs with ETA to TDA	None
06 00	3	4	Model	ASWOC	Relays cone of courses	None
	3	5	ASWOC	Model	Acknowledge	A
	3	7	Model	ASWOC	Plotter concurs with cone of courses	None
	4	1	ASWOC	ASWFCO	Order search area	A+B
	4	2	ASWFCO	ASWOC	Acknowledge	A
08 00	5	1	Model	ASAC	Helo reports first buoy dropped	None

TABLE 2. MEASUREMENT SEGMENTATION BASED ON TEAM MEMBER COMMUNICATION, CONT.

TIME	SEGMENT	EVENT	COMMUNICATOR	TO	ACTION	MEASURES
	5	2	ASAC	Model	Acknowledge buoy drop	A
	5	3	ASAC	ASWOC	Report buoy drop	A+B
	5	4	ASWOC	ASAC	Acknowledge	A
	5	5	ASWOC	Model	Report Kingpin to A/S	A+B
	5	6	ASAC	Model	Standby for buoy drop	A
08 30	5	7	ASAC	Model	Order buoy drop	A+C
	5	8	Model	ASAC	Report buoy drop	None
	5	9	ASWOC	Model	Report buoy pattern to A/S	A+B
09 20	5	10	ASAC	Model	Standby for buoy drop	A
	5	11	ASAC	Model	Order buoy drop	A+C
	5	12	Model	ASAC	Reports buoy drop	None
10 00	5	13	ASAC	Model	Standby for buoy drop	A
	5	14	ASAC	Model	Order buoy drop	A+C
	5	15	Model	ASAC	Reports drop complete	None
	5	16	ASAC	ASWOC	Reports drop complete	A
	5	17	ASWOC	Model	Reports drop complete	A+B
10 20	6	1	Model	ASWOC	SAU commander orders zigzag pattern	None
	6	2	ASWOC	Model	Acknowledge	A
	6	3	ASWOC	Model	Passes zigzag pattern to bridge	A+B
08 00	7	1	ASWOC	Model	Requests weapons policy	A
	7	2	Model	ASWOC	Sends weapons policy	None
	7	3	ASWOC	Model	Acknowledge	A
	7	4	ASWOC	Model	Sends weapons policy to bridge	A+B
	7	5	ASWOC	ASAC	Sends weapons policy	A+B
	7	6	ASAC	ASWOC	Acknowledge	A

TABLE 2. MEASUREMENT SEGMENTATION BASED ON TEAM MEMBER COMMUNICATION, CONT.

TIME	SEGMENT	EVENT	COMMUNICATOR	TO	ACTION	MEASURES
	7	7	ASWOC	ASWFCO	Sends weapons policy	A+B
	7	8	ASWFCO	ASWOC	Acknowledge	A
	8	1	Model	ASAC	Helo conducting MAD search	None
	8	2	ASAC	Model	Acknowledge	A
	8	3	Model	ASAC	Helo reports MAD contact	None
	8	4	ASAC	Model	Acknowledge	A
	8	5	ASAC	ASWOC	Report MAD contact	A+B
	8	6	ASWOC	ASAC	Acknowledge	A
	8	7	ASWOC	Model	Report MAD contact to A/S	A+B
	8	8	Model	ASWOC	Acknowledge	None
	8	9	ASWOC	ASWFCO & Model	Report MAD contact	A+B
	8	10	ASWFCO	ASWOC	Acknowledge	A
	9	1	ASAC	ASWOC	Report conducting MADVEC	A
	9	2	ASWOC	Model	To A/S Report conducting MADVEC	A
	9	3	Model	ASWOC	Acknowledge	None
	9	4	ASAC	Model	Vectors to helo	A+B
	9	5	Model	ASAC	Acknowledge vectors	None
	9	6	ASAC	Model	Vectors to helo	A+B
	9	7	Model	ASAAC	Acknowledge vectors	None
	9	8	ASAC	Model	Vectors helo	A+B
	9	9	Model	ASAC	Acknowledge vectors	None
	9	10	Model	ASAC	Report MAD contact	None
	9	11	ASAC	Model	Acknowledge	A
	9	12	ASAC	ASWOC	Report MAD contact	A+B

TABLE 2. MEASUREMENT SEGMENTATION BASED ON TEAM MEMBER COMMUNICATION, CONT.

TIME	SEGMENT	EVENT	COMMUNICATOR	TO	ACTION	MEASURES
	9	13	ASWOC	ASAC	Acknowledge	A
	9	14	ASWOC	Model	Report MAD contact to A/S	A+B
	9	15	Model	ASWOC	Acknowledge	None
	9	16	ASWOC	ASWFCO & Bridge	Report MAD contact	A+B
	9	17	ASWFCO	ASWOC	Acknowledge	A
	9	18	Model	ASWOC	Bridge acknowledge	None
	10	1	ASWFCO	Model	New search area to sonar	A+B
	10	2	Model	ASWFCO	Acknowledge	None
	10	3	ASWFCO	ASWOC	New search area	A+B
	10	4	ASWOC	ASWFCO	Acknowledge	A
17 00	11	1	Model	ASWOC	Execute zigzag	None
	11	2	ASWOC	Model	Acknowledge	A
	11	3	Model	ASWOC	Initial zigzag course from plotter	None
	11	4	ASWOC	Model	Acknowledge	A
	11	5	ASWOC	Model	Tell bridge execute zigzag	A+B
	11	6	Model	ASWOC	Confirm course change	None
	11	7	ASWOC	Model	Acknowledge	A
	12	1	ASAC	Model	Vectors helo	A+B
	12	2	Model	ASAC	Acknowledge	None
			REPEAT 12.1 AND 12.2 AS REQUIRED			
	12	3	Model	ASAC	Helo reports MAD contact	None
	13	1	Model	ASWOC	Plotter reports entering TDA	None
	13	2	ASWOC	Model	Acknowledge	A
	13	3	ASWOC	Model	Informs bridge entering TDA	A
	13	4	Model	ASWOC	Acknowledge	None

TABLE 2. MEASUREMENT SEGMENTATION BASED ON TEAM MEMBER COMMUNICATION, CONT.

TIME	SEGMENT	EVENT	COMMUNICATOR	TO	ACTION	MEASURES
	13	5	ASWOC	Model	Entering TDA to A/S	A
	13	6	Model	ASWOC	Acknowledge	None
	13	7	ASWOC	ASWFCO	Entering TDA	A
	13	8	ASWFCO	ASWOC	Acknowledge	A
20 00	14	1	Model	ASWOC	Orders course change	None
	14	2	ASWOC	Model	Orders course change	A+B
	14	3	Model	ASWOC	Acknowledge	None
	15	1	Model	ASAC	Helo reports MAD contact	None
	15	2	ASAC	Model	Acknowledge	A
	15	3	ASAC	ASWOC	Report MAD contact	A+B
	15	4	ASWOC	ASAC	Classification and weapons status	A+B
	15	5	ASAC	Model	Classification and weapons status	A+B
	15	6	Model	ASAC	Acknowledge	A
	15	7	Model	ASWOC	Plotter reports sub course and speed	None
	15	8	ASWOC	Model	Acknowledge	A
	15	9	ASWOC	Model	Report MAD, course and speed to A/S	A+B
	15	10	Model	ASWOC	Acknowledge	None
	15	11	ASWOC	Model	Report MAD to bridge	A+B
	15	12	Model	ASWOC	Acknowledge	None
22 00	16	1	Model	ASWOC	Orders course change	None
	16	2	ASWOC	Model	Orders course change	A+B
	16	3	Model	ASWOC	Acknowledge	None
24 00	17	1	Model	ASWOC	Orders course change	None
	17	2	ASWOC	Model	Orders course change	A+B
	17	3	Model	ASWOC	Acknowledge	None

TABLE 2. MEASUREMENT SEGMENTATION BASED ON TEAM MEMBER COMMUNICATION, CONT.

TIME	SEGMENT	EVENT	COMMUNICATOR	TO	ACTION	MEASURES
	18	1	Model	ASAC	Helo reports lost contact	None
	18	2	ASAC	Model	Acknowledge and vector helo	A+B
	18	3	ASAC	ASWOC	Report lost contact	A+B
	18	4	ASWOC	ASAC	Acknowledge	A
	18	5	ASWOC	Model	Report lost contact to A/S	A+B
	18	6	Model	ASWOC	Acknowledge	None
	18	7	ASWOC	Model	Report lost contact to bridge	A+B
	18	8	Model	ASWOC	Acknowledge	None
26 00	19	1	Model	ASWOC	Orders course change	None
	19	2	ASWOC	Model	Orders course change	A+B
	19	3	Model	ASWOC	Acknowledge	None
	20	1	Model	ASWFCO	Sonar reports sonar contact	None
	20	2	ASWFCO	Model	Orders sonar reports on loudspeaker	A
	20	3	ASWOC	Model	Reports sonar contact to A/S	A+B
	20	4	ASWOC	Model	Executes attack plan to A/S	None
	20	5	Model	ASWOC	Acknowledge	None
	20	6	ASWOC	ASAC	Report sonar contact	A
	20	7	ASAC	Model	Report sonar to helo	A
	20	8	ASWOC	ASAC	Orders helo clear	A
	20	9	ASAC	ASWOC	Acknowledge	A
	20	10	ASAC	Model	Orders helo clear	A
	20	11	Model	ASAC	Acknowledge	None
	21	1	ASWOC	Model	Report sonar contact to bridge	A
	21	2	ASWOC	Model	Report attack plan executed to bridge	A

TABLE 2. MEASUREMENT SEGMENTATION BASED ON TEAM MEMBER COMMUNICATION, CONT.

TIME	SEGMENT	EVENT	COMMUNICATOR	?	ACTION	MEASURES
	21	3	ASWOC	ASWFCO	Report attack plan executed, prep basket starboard	A
	22	1	Model	ASWFCO	Report sonar contact	None
	22	2	ASWOC	Model	Order new course to bridge, intent	A+B
	22	3	ASWOC	Model	Upgrade contact to A/S	A+B
	22	4	ASWOC	Model	Report new course, firing intent to A/S	A+B
	22	5	Model	ASWOC	Acknowledge	None
	23	1	ASAC	ASWOC	Report helo clear	A
	23	2	ASWOC	ASAC	Acknowledge	A
29 00	24	1	ASWFCO	ASWOC	Reports firing bearing	A+B
	24	2	ASWOC	ASWFCO	Orders system to launch status	A
	24	3	ASWOC	Model	Pass firing bearing to A/s	A+B
	24	4	ASWFCO	ASWOC	Reports system ready to fire	A
	24	5	ASWOC	Model	Pass firing bearing to bridge	A+B
	24	6	Model	ASWOC	Bridge reports firing bearing clear	None
	24	7	ASWOC	ASWFCO	Orders weapon fired	A
	24	8	ASWFCO	Model	Completes weapons switchology	A
30 00	25	1	ASWFCO	ASWOC	Reports weapon fired	A+B
	25	2	ASWOC	Model	Reports weapon fired to A/S	A+B
	25	3	ASWOC	ASAC	Reports weapon fired	A+B
	25	4	ASAC	Model	Reports weapon fired to helo	A+B
	25	5	Model	ASAC	Acknowledge	None
	25	6	ASWOC	Model	Informs bridge weapon fired	A+B
	25	7	ASWOC	Model	Inform plotter	A+B
	26	1	ASWFCO	ASWOC	Relays water entry point	A+B

TABLE 2. MEASUREMENT SEGMENTATION BASED ON TEAM MEMBER COMMUNICATION, CONT.

TIME	SEGMENT	EVENT	COMMUNICATOR	TO	ACTION	MEASURES
	26	2	ASWOC	ASWFCO	Acknowledge	A
	26	3	ASWOC	Model	Water entry point to A/S	A+B
	26	4	Model	ASWOC	Acknowledge	A
	26	5	ASWOC	Model	Water entry point to bridge	A+B
	26	6	Model	ASWOC	Acknowledge	A
	26	7	ASWFCO	ASWOC	Relay shot status	A+B
	26	8	ASWOC	ASWFCO	Acknowledge	A
	26	9	ASWOC	Model	Weapon safe time to A/S	A+B
	26	10	Model	ASWOC	Acknowledge	None
	26	11	ASWOC	Model	Orders retirement to bridge	A+B

Measures: A - Verification that the event occurred

B - Accuracy check of the information content

C - Helo position

TABLE 3. START/STOP LOGICS FOR SCENARIO SEGMENTS.

Segment	Start	Stop
1.	1.1	Time = 03 minutes
2.	2.1	2.13
3.	3.1	3.7
4.	4.1	4.1 + 5 sec or 4.2
5.	5.1	5.15
6.	6.1	6.3
7.	7.1	7.4
8.	8.1	8.9 + 5 sec
9.	9.1	9.16 + 5 sec or 9.17
10.	10.1	10.4 or 10.3 + 5 sec
11.	11.1	11.6 and 11.7
12.	12.1	12.3
13.	13.1	13.3 and 13.4
14.	14.1	14.1 and 14.2
15.	15.1	15.9 and 15.11 and 15.12
16.	16.1	16.1 and 16.2
17.	17.1	17.1 and 17.2
18.	18.1	18.5 and 18.7 and 18.8
19.	19.1	19.1 and 19.2
20.	20.1	20.8 and 20.9
21.	21.1	21.3 and 21.2
22.	22.1	22.4 and 22.5
23.	23.1	23.1 + 5 sec
24.	24.1	24.8
25.	25.1	25.2 and 25.3 and 25.6
26.	26.1	26.11

It is anticipated that, during completion of any given segment, a large number of communications will take place in addition to the specified critical communications. A count of these communications will be taken also.

Start and stop times for each segment will be recorded. It is expected that many of the measurement segments will be occurring simultaneously. For example, at the conclusion of Segment 1, a series of interactions will begin between the ASWOC, ASAC, and helicopter. These interactions constitute Segment 2. During the same time period, the ASWOC will probably be interacting with the assist ship, bridge, and plotter models (Segment 3). Accommodation must be made in the machine design to have several open measurement segments at any given time during operation of the device.

CANDIDATE MEASURES. Measurement will be made at three different levels: system, team, and individual performance. Specific types of measures to be taken at each measurement level are listed in Tables 4, 5, and 6.

System level measurement. System level measurement includes the record of the position and behavior of all hardware elements of the ASW problem. This includes position and movement of ownship, the sister ship, helicopters, buoys, and the target submarine. These measures are to be recorded, along with a time marker, a minimum of once per second.

These measures will be used to develop a time history record of the overall actions of the entire system, friendly assets, and opposing assets. They can be used to determine whether the SAU is moving in an appropriate manner to close on the datum, whether search assets such as helicopters and buoys are deployed in an optimal position, whether the SAU is able to close to an appropriate firing position, and whether they are able to accomplish an effective weapons delivery.

Team level measurement. This category of measurement includes the measures of overall team effectiveness shown in Table 5. These measures can be divided into three main subcategories: time measures, error measures, and communication measures.

Team measures involve the performance and interaction of two or more of the three positions filled by trainees. Many of these measures can be calculated as a composite of information obtained from system level measures (e.g., water entry point (WEP) miss distance is determined by the target submarine X and Y position, and the WEP X and Y position).

Time measures are determined by tracking the time history of events shown in the Segmentation Table (Table 2).

TABLE 4. CANDIDATE MEASURES OF SYSTEM PERFORMANCE.

OWN SHIP

- X Position
- Y Position
- Course
- Speed

ASSIST SHIP

- X Position
- Y Position
- Course
- Speed

TARGET SUBMARINE

- X Position
- Y Position
- Course
- Speed

TIME INTO EXERCISE

- H:M:S

HELO

- X Position
- Y Position
- Course
- Speed

BUOYS

- X Position
- Y Position

DATUM

- X Position
- Y Position

WEAPON WATER ENTRY POINT

- X Position
- Y Position

TABLE 5. CANDIDATE MEASURES OF TEAM PERFORMANCE.

<u>TIME</u>

Attack time I (Time from Step 1.1 to Step 24.8)
Attack time II (Time from Step 20.1 to Step 24.8)
Buoy plant time (Time from Step 1.1 to Step 5.17)
Time in TDA (Time from Step 11.1 to Step 24.8)
Time in Dog Box (Time from Step 20.1 to Step 23.1)

<u>ERRORS</u>

Water Entry Point Miss Distance
Buoy Miss Distance

<u>COMMUNICATIONS</u>

Total Number of Communications
Mean Length of Communications (Sec.)
Mean Message Latency (From time of reportable event until report)
Number of Assists (Prompts by Another Team Member)

TABLE 6. CANDIDATE MEASURES OF INDIVIDUAL PERFORMANCE.

ASWOC

TIME

Time to Send Helo Orders (Time from Step 1.1 to Step 2.1)
Time to Order Search Area (Time from Step 3.7 to Step 4.1)
Zigzag Pattern Order Time (Time from Step 6.1 to Step 6.3)
Time to Obtain Weapons Policy (Time from Step 1.1 to Step 7.2)
Firing Time (Time from Step 23.1 to Step 24.7)

ERRORS

Time contact is in baffles
Incorrect weapons selection

COMMUNICATIONS

Total Number
Mean Length
Number Incorrect
Number Missing
Number Late
Mean Latency

ASAC

TIME

Buoy Drop Time (Time from Step 1.1 to Step 2.13)
Time to Report MAD Contact (Time from Step 15.1 to Step 15.3)
Time to Clear Helo (Time from Step 20.6 to Step 23.1)

ERRORS

Buoy Position Error
MADVEC Course Error
Scram Course Error

COMMUNICATIONS

Total Number
Mean Length
Number Incorrect
Number Missing
Number Late
Mean Latency

TABLE 6. CANDIDATE MEASURES OF INDIVIDUAL PERFORMANCE, CONT.

ASWFCO

TIME

Search Arc Assignment (Time from Step 9.16 to Step 10.1)
WEP Report Time (Time from Step 25.1 to Step 26.1)
Shot Status Report Time (Time from Step 25.1 to Step 26.7)

ERRORS

Search Arc Error
Firing Bearing Error
WEP Error

COMMUNICATIONS

Total Number
Mean Length
Number Incorrect
Number Missing
Number Late
Mean Latency

Individual level measurement. This category includes measures of performance for each of the three individual positions (ASWOC, ASAC, and ASWFCO). Again, the performance measures for these individuals will include measures of times, errors, and communications.

Measures of time will consist mainly of the time required to process a unit of information received from another team member and to perform a required action or communication using that information. These measures will be obtained by tracking the time history of events shown on the Segmentation Table (Table 2). Measures of error will be obtained by examining all communications shown on the Segmentation Table to uncover, tally, and evaluate missing, inaccurate, or untimely communications.

Communication measures will include counts and lengths of communications during individual segments and during the exercise as a whole.

It should be emphasized that the variables specified for measurement in Tables 4, 5, and 6 apply specifically to the scenario used here which involves two ships, one submarine, and an unarmed helicopter. If changes, additions, or deletions are made to the assets involved in the scenario, corresponding additions or deletions will have to be made in the list of measurement variables. For example, position, course, speed, and time information will be needed for every air and sea asset in the exercise.

In addition, the measurement system will have to be able to calculate and accommodate combinations of any of these system variables into more complex measures defined by the researcher or user. For example, the SAU's closure rate with the submarine or ratios of incorrect to correct communications will be needed in the future. Sufficient capability for the real-time calculation of such measures must be provided.

SECTION III

RESEARCH EMPHASES

Specific options for a research approach are offered in this section based on the literature, observations of current team training, and an analysis of ASW team tasks. The point of view implied here is that the research use of the research tool must be identified before meaningful hardware and software specifications can be made.

The broad research emphases selected are:

a. Communications in team training, for this is a key research area (see Appendix B). These communications are the team interactions; they are distinct problems as observed in the field and are essential to promoting beneficial group phenomena.

b. Effective team performance measures, for these are required to identify team phenomena. They determine what is accomplished in team training, and are necessary for performance feedback (see Appendix B).

c. Training with synthetic team members, for the entire team cannot be present. Modeling of synthetic team members is a major step toward understanding the underlying phenomena, and such models can be used for feedback and adaptive interaction.

d. Evolutionary development of a demonstration system, for the type of system described is a distinct advancement of the state-of-the-art, and should proceed in calculated steps.

Given the above decisions about what research to emphasize, the current section attempts to derive the resulting implications for hardware and software. A problem-oriented organization is used: if training is to be accomplished, albeit in a research environment, (1) training objectives must be specified, and the issues of (2) feedback, and (3) adaptive variables must be addressed with appropriate research. Also, the hardware and software must provide for (4) the needs of instructors and researchers. Furthermore, (5) the characteristics of communication research, and (6) related performance measurement, must be considered. And, finally, (7) future research possibilities should be noted to indicate needs for flexibility in design. Each of these topics is taken up in order in the following paragraphs.

TRAINING OBJECTIVES

A research tool for the purpose of investigating team training issues must necessarily involve cases of real training. This presents a dilemma, since both the literature and the training observation accomplished in this

study point out that specific team training objectives have not been well defined, and no one seems to be able to articulate just what it is that is accomplished during team training.

However, examination of the collective definitions of "group" and "team" include the following features: (1) a network of relevant communications, (2) a shared sense or identity, and (3) shared goal disposition with associated norms. Furthermore, the literature supports the conclusion that desirable group phenomena result from these conditions. Therefore, as a beginning, to provide a basis for detailed exploratory research, it is recommended that these requisite conditions be adopted as training goals. In particular, the flow of communications, understanding of mutual relationships, and quantification of specific team goals, are weaknesses observable in current team training. Also, the Operational Sequence Diagrams (Figure 2) contain information through which team members can prompt each other when communications are omitted, delayed, or incorrect; team training should emphasize such helpful actions. Training toward these ends should establish a basic functioning team upon which further research can develop.

The following sections expand upon specific variables which can be emphasized within the foregoing framework.

FEEDBACK

The literature strongly supports the notion that feedback (or knowledge of results) is an exceedingly strong training variable, and that research in this area will have a high probability of payoff. In particular, the kind and amount of individual and team feedback and the immediacy of feedback, requires heavy research emphasis. It is believed that comparison between operator performance and that of team member models can be used for automatic immediate feedback, and performance measurement can be used to support post-exercise instructor debriefing. In view of the scenario analyzed and the procedure currently used in operational team training, feedback given during a training exercise and feedback given after a training exercise requires investigation.

Specific options to be considered are:

a. Provide a prompt to the operator (ASWOC, ASAC, or ASWFCO) showing the specific communications which would be made by the model for that station.

b. Display the model communications as in (a), but only if: (1) human operator communications are omitted or seriously delayed; (2) operator communication is in error (type or content); or (3) after the operator communicates, model communication is displayed for verification to reinforce, as well as to correct. It should be noted that the "individual" who

can provide a helping prompt (see the OSD, Figure 2) is often one who will be modeled in the device under consideration; therefore, such prompts become a form of automated feedback.

The following hardware features are considered necessary to effectively implement the above options:

a. A color Cathode Ray Tube (CRT) display with alphanumeric and line-drawing graphic capability.

b. An alerting mechanism, including an audible tone, warning lamp, and use of CRT color.

c. Variable function response keys or touch-panel array.

d. Computer-generated speech messages.

ADAPTIVE VARIABLES

The ASW problem lends itself to the manipulation of adaptive training variables of a number of different types. Some of the more interesting adaptive variables are:

a. Augmenting the trainee's displays with prompting information generated by performance measurement or the model of the trainee's position.

b. Manipulating positive or negative features of team behavior of trainee models to provide degrees of difficulty in the team environment.

c. Increasing problem (setup) difficulty. Based on the analysis performed in this study, the following sequence is recommended for initial research: (1) single ship, (2) single + one aircraft, (3) dual ship + one aircraft, trainees in the assist ship, (4) dual ship + one aircraft, trainees and the Search Attack Unit Commander (SAUC), (5) dual ship + 2 aircraft, SAUC, and (6) dual ship + 2 aircraft, SAUC, smarter adversary. Within this sequence, difficulty can be modified by increasing the required level of maneuvering.

d. Providing step-wise or non-real-time problem presentation (again, when a single operator is performing).

e. Implementing a more intelligent submarine adversary.

While many of the system features required for the above adaptive variables are obvious, the following are listed for emphasis:

a. Flexible team member and submarine models, anticipating possible future modifications or expansions.

b. Problem freeze under control of an automatic performance monitor, with restart at any designated station.

c. Either interactive or automatic problem setup for quick and easy changes in problem difficulty.

INSTRUCTOR/RESEARCHER CONSIDERATIONS

It should be clear that a research tool should be designed with the needs of the researcher in mind; and, further, since training research will also involve an instructor, the needs of the instructor must also be considered (without exploding costs with the inclusion of a fully integrated instructor work station). To some extent, the design may simultaneously satisfy the needs of instructor and researcher; and also, research interaction will be primarily off-line after the end of training exercises.

Features needed for the instructor/researcher include:

a. Interactive problem setup.

b. Problem control--start, freeze, continue, stop.

c. Comprehensive plots of track histories, time listings of events and communications, and selected performance measures.

d. Audio monitoring capability for observers since communications are divided over a number of channels.

e. Standard format records for off-line analysis, transportable media (magnetic tape), and convenient summary data analysis for data quality monitoring.

COMMUNICATIONS

A major research and training area is that of team communications. There is a need for a means of detailed analysis of communications occurring during simulated ASW exercises. This analysis can strive for two goals: (a) the formulation of measurement illuminating the nature of team interactions, and (b) a basis for establishing standardized communication where there is none present.

Given a capability for automatic recognition of speech, the once impossible task of detailed measurement of volumes of speech data becomes feasible. The multitude of potential communication measures can be automatically, or semi-automatically, processed to generate large sets of candidate measures which can be subjected to statistical selection techniques. In this way, the task of identifying new and meaningful measures of team interaction becomes a goal within reason.

While ASW communications to destinations outside the Combat Information Center are standardized and formal, the equivalent standardization does not exist for communications within the CIC. It can be hypothesized that such standardization can greatly enhance team interaction. Again, a capability for speech recognition can provide the tool sorely needed for methodically analyzing and standardizing the internal communications.

Hardware features to support the above communications research include the following:

a. Multi-channel audio recording.

b. Speech recognition/understanding for three talkers.

c. Off-line (semi-automatic) speech data reduction for (1) quick end-of-run analysis and (2) extended end-of-day analysis.

OFF-LINE ANALYSIS OF COMMUNICATIONS DATA

The envisioned team training research will provide an excellent environment in which to investigate the communication behavior and performance of real-world teams during the performance of complex tasks. In-depth communication studies of this kind are likely to suggest ways that the efficiency of the team interactions may be improved, as well as suggesting areas for increased or altered training emphasis. This suggested use of the research device will require the capability for a detailed linguistic analysis of the content of all communications between team members.

The process of performing a linguistic analysis of oral communications is not simple. The primary reason is that natural oral communication is exceptionally complex and unruly. In contrast to the kind of carefully "laundered, sanitized, starched, and pressed" prose usually studied by linguists (Chapanis, 1971), real oral communication consists largely of utterances which are, in full or in part, ungrammatical, incomplete sentences or ideas, unintelligible phrases, and non-words.

Some problems in the analysis of oral communications are described by Chapanis, Parrish, Ochsman, and Weeks (1977). One kind of problem involved words which received a non-standard pronunciation, due either to the speaker's regional accent or to an actual mispronunciation of the word. Another class of problem involved partial or incomplete words such as "em," "cuz," or "uh." Colloquial or slang words presented another difficulty. This included words such as "yup," "nope," and "jobbers." Contractions such as "gonna," "d'ya," and "gotcha" were another source of analysis difficulty. In addition, frequent interjections such as "hmmm," "ugh," and "whew" were found to be a common part of the normal communications. Finally, totally unintelligible words were not uncommon, although these could usually be identified by the context in which they occurred.

In addition to the irregularities in the individual words found in normal oral communication, word strings (they can scarcely be described as sentences) follow few grammatical rules, and, taken individually, often make little sense. Figure 4 presents a quotation from a communication protocol discussed by Chapanis (1976) and demonstrates this point.

Although the verbal exchange shown on Figure 4 appears strange and awkward when read, it is important to note that these spoken words apparently made perfect sense to the team members who exchanged them. The required information was effectively transferred, and the problem was correctly solved.

Because of the word recognition problems and sentence structure unruliness described above, any attempts at automatic linguistic analysis are far beyond the current state-of-the-art. This suggests that a capability must be provided which will permit an off-line linguistic analysis of the communication contents.

This requirement can be met by the inclusion of a multi-channel tape recorder configured such that each channel is dedicated to one of the team members. The training sessions will be accurately recorded as they are taking place. After the conclusion of the session, the tapes will be transcribed into hard copy and independently verified. The text of the training sessions, reproduced in this manner, can then be entered into magnetic tape or disk storage for computer analysis. Some of the communication measures which could be subsequently derived are (a) total number of words, (b) total number of unique words, (c) type/token ratios, (d) total number of messages, (e) mean and variance of message length, (f) use of different parts of speech, (g) coefficient of variation in words, messages, and (h) commonality of word usage among teams.

FUTURE POSSIBILITIES

While the current study is examining a specific selected application, a number of related problem areas have been apparent. Since a tool is often used for purposes other than those originally intended, it is believed appropriate to give some design consideration to future possibilities.

It has been observed that much of current team training is devoted to training tactics. Although tactical decision making is not a team task but is the responsibility of the ASWOC, the training of ASW tactics is an intriguing and challenging subject, and perhaps this research tool could also find application in this important area.

Similarly, the investigation of team training may point the way to the design of a number of cost-effective part-task trainers. The current tool could also find application in such design efforts.

The current Navy jobs and task assignments have been taken as a given in the current study, but it is not at all certain that the current jobs are optimally defined. The research tool as presently envisioned would lend itself readily to the re-allocation of functions between team members.

Subject A:	Okay, I got you but it's wider than it right?
Subject B:	Yeah, a little bit wider.
Subject A:	A little bit wider...Okay wait a second. Uh how wide is the socket is it you know the socket itself is it
Subject B:	Okay
Subject A:	wide or thin cuz I have uh two two just about like that what you described.

Figure 4. Portion of oral communication protocol from cooperation problem solving study (Chapanis, 1976).

The above are only exemplary: it should be easy to greatly expand the growth potential for the present research tool. And, such consideration of potential growth could lead to a better design specification.

SECTION IV

SYSTEM CONCEPT

The purpose of this section is to present a system concept for the proposed team training demonstration system: a general picture of what the demonstration system will look like, what kinds of hardware it will use, and what it will do. A well-formulated system concept will serve in a variety of capacities to aid in the further design, development, and refinement of the original basic notion.

The approach in this section is, first of all, to answer the question "What will the system look like?," and give a general description of the hardware suite. Secondly, an overall view of the functional capabilities of the system is offered to answer the question "What will the system do?"

WHAT WILL THE SYSTEM LOOK LIKE?

An observer who comes upon the completed team training demonstration system will see a system which is a combination of a laboratory and of a CIC slice-of-life. There are up to five human participants in this system: three "students" (ASWOC, ASWFCO, ASAC), one "instructor," and the researcher. The "instructor" and researcher may, in fact, be a single individual. For the initial look at the functioning system, assume that all these humans are present.

Before the students arrive, the instructor and researcher cooperate to set up the ASW problem to be used that day. Starting with a skeletal scenario and aided by computer prompts and sets of menus, the instructor and researcher proceed to assign initial positions and speeds to the players, to set up the environment (ocean conditions, visibility, wind, weather), and to establish the weapons and motion capabilities of all craft in the exercise. The researcher, choosing from a computer-presented menu, assigns and sets up performance measures to be used during the problem and selects data to be recorded by the computer during the exercise.

Sometime during this set-up process, the students arrive and sit down at their consoles. The physical arrangement they see is a pattern of three student consoles sitting at the vertices of a roughly equilateral triangle, facing outward, while the instructor/researcher station sits at the center of this triangle. (See Figure 5) The consoles the students see are not operational consoles, but functional facsimiles. Should the observer look over the ASWOC's shoulder, for example, the console picture he would see might look like Figure 6. Although their physical appearance is identical from a functional point of view, the consoles are individually tailored for each team member's role. The ASWOC's console mimics an OJ197 console, while the ASWFCO's and the ASAC's consoles mimic an OJ194 console operating in

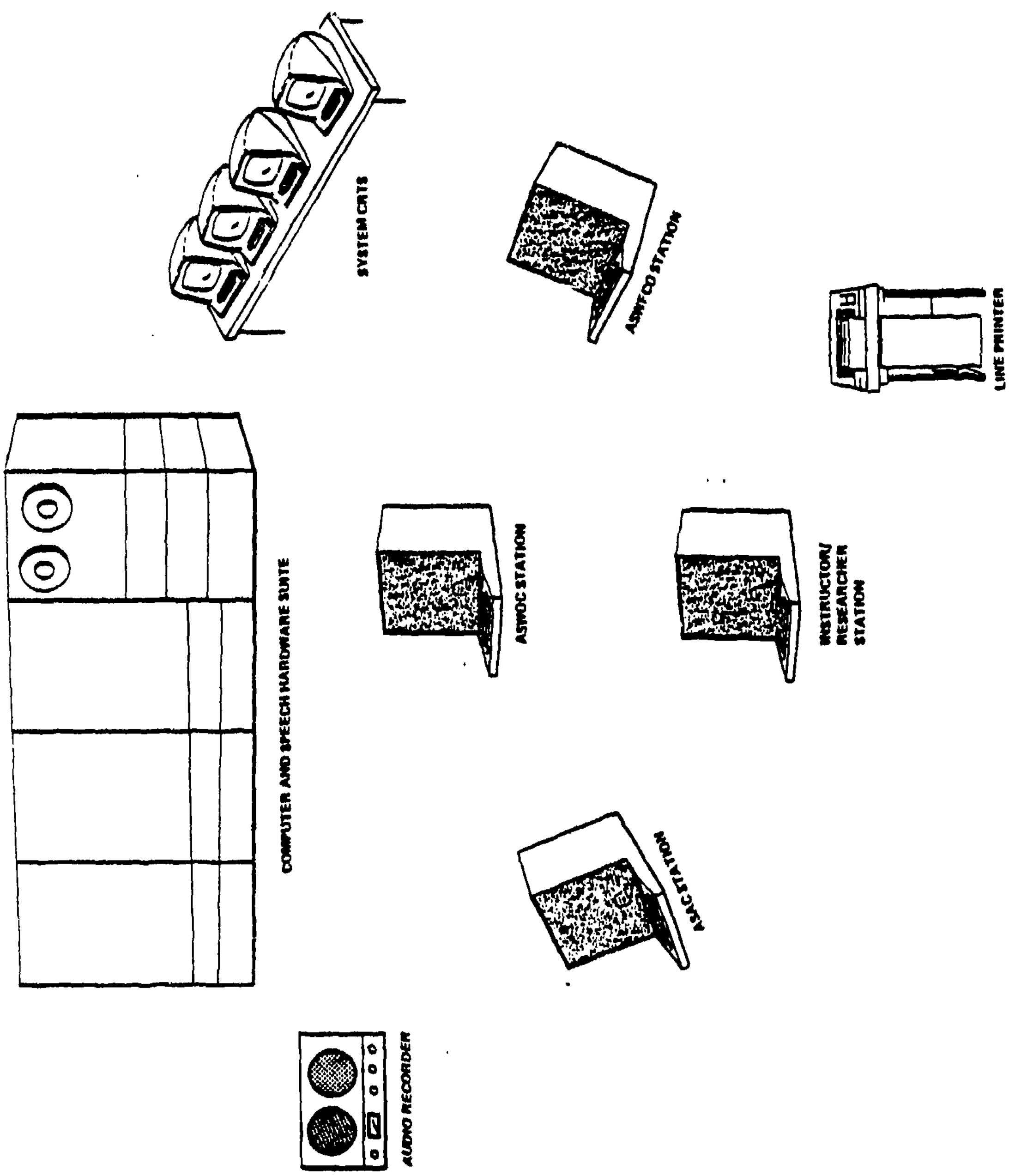


Figure 5. Team Training System - A concept of physical layout.

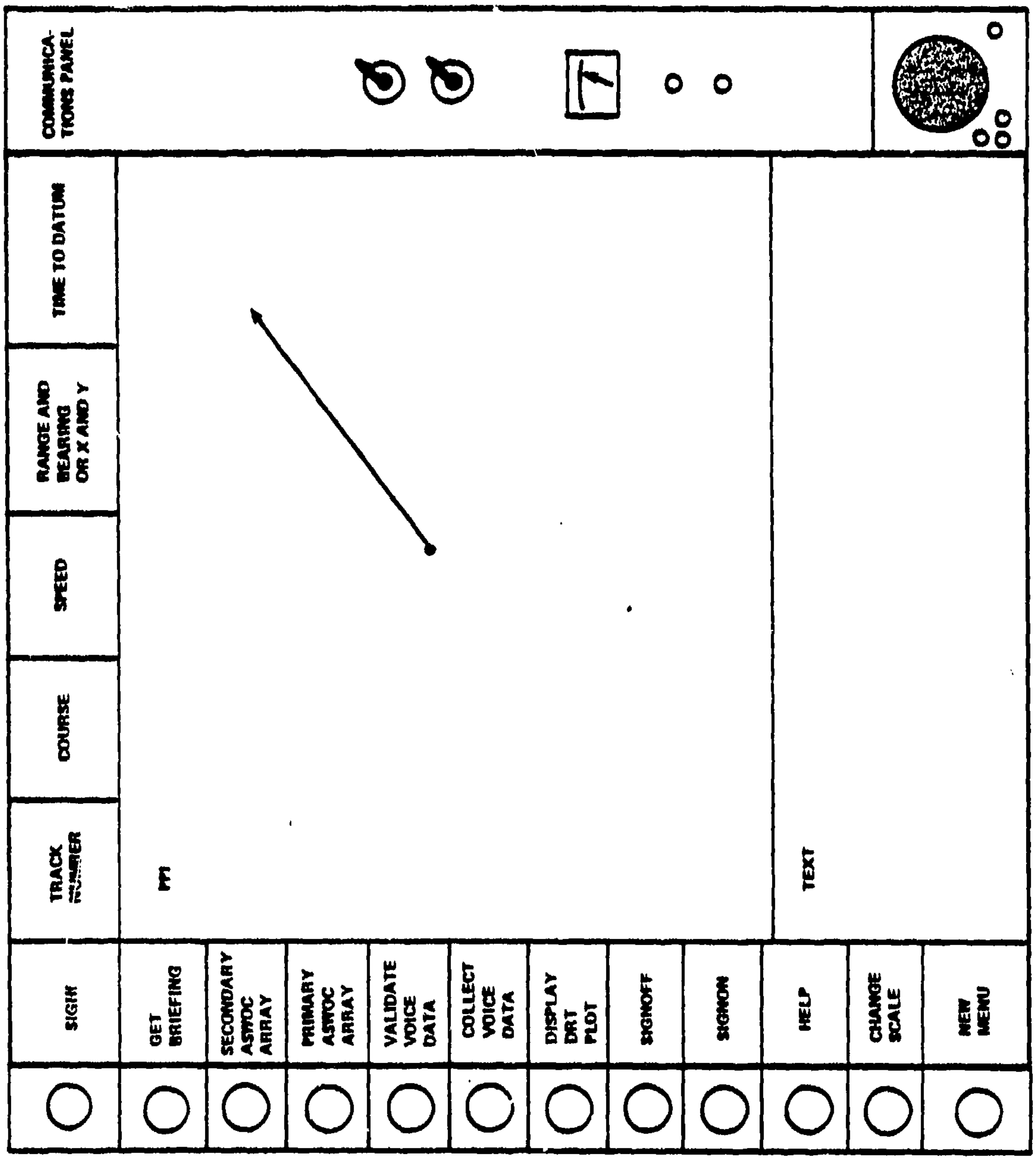


Figure 6. ASWOC display.

the weapon and the ASAC modes, respectively. Each console also contains a standard keyboard to permit entry of numeric data and to allow each student to sign on.

Since the set of students have not used the system before, they sign on individually and begin to receive instruction from the computer as to how the system works and how to get full use of their consoles. As part of the process of familiarization, the students are told of the speech recognition and generation systems and their limitations. The computer collects voice reference data from each student and stores the voice reference patterns for later use.

Once everyone is ready and problem set up is complete, the system gives the students an intelligence briefing which explains the state of their tactical world as they take over, including information about a possible submarine in the area and its rough location from an intelligence report. This briefing is intended to inform the students about the capabilities of their ship, the character of the air support, the hypothesized hostile submarine type, and various other environmental information.

When the briefing is complete, the problem begins. Motion of all craft in the exercise begins, and the team members begin to respond to this simulated ASW environment as if it were the real thing - the game is afoot! The full ASW team - ownship, assist ship, and supporting aircraft - pursue their roles in attempting to localize the submarine. During this activity, the team members speak to each other and to all the other simulated support personnel as needed, and, at appropriate times, the simulated support personnel respond to team member communications and initiate communications of their own.

Sometime early on in the problem, sonar contact with a possible submarine is reported and additional contacts are sought to establish the submarine's course. As the pace picks up, ownship moves in on the submarine, fires a weapon, and retires to a safe range.

As all this activity is going on, the instructor occasionally moves around to watch over team members' shoulders to see the problem as they see it. Back at his console, the instructor can see the whole picture: positions of all friendly craft as well as the position and the path of the submarine, as shown in Figure 7.

When the problem is concluded, the team members are debriefed individually by the computer at their consoles and then collectively by the instructor. As an aid for this collective debriefing, the instructor has available a computer-created plot of the motion of all craft in the exercise, annotated to show positions at crucial times during the problem.

When the problem is complete, the researcher may consult with the instructor, comparing observations and computer-generated evaluation with the instructor's own assessment. The researcher can request a hard copy listing of data the

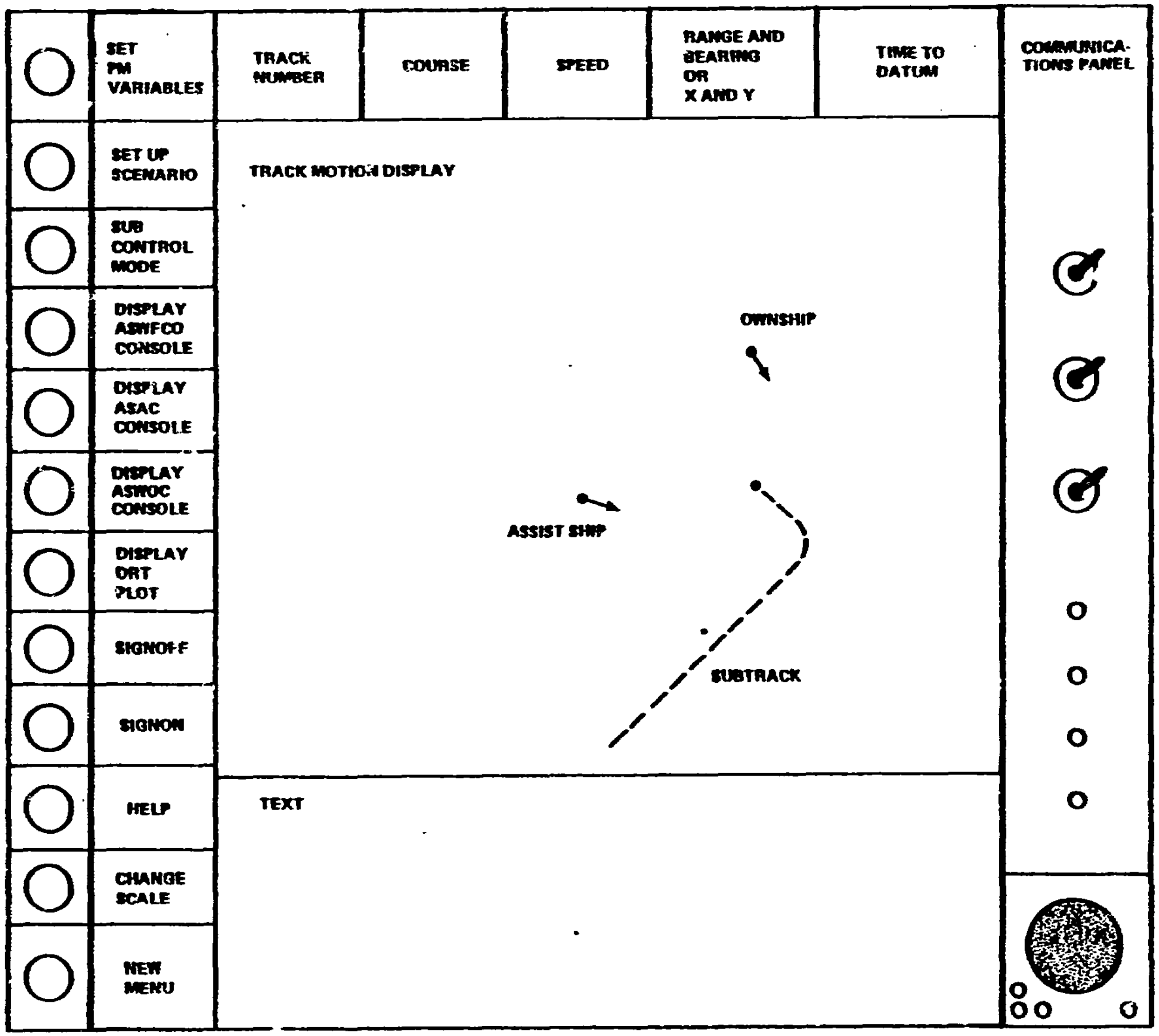


Figure 7. Instructor/researcher display.

computer gathered during the problem and may store other information on magnetic tape. He also has available to him an event-marked tape recording of all verbal communications which occurred during the problem.

WHAT EQUIPMENT IS NEEDED?

A team training demonstration system like the one just described needs computers, speech recognition and generation equipment, system CRTs, display consoles, mass data storage, a line printer, and a multi-channel tape recorder. A potential system configuration is sketched in Figure 8. The individual components are:

a. Four medium-sized minicomputers on the order of a Data General Eclipse S-230 or a DEC PDP-11/24.
b. Two or three NEC DP-200 connected speech recognition systems. This NEC device is so new that its specifications are not yet available. The older DP-100 can handle two channels - hence two speakers - simultaneously, but it is not known yet if the DP-200 will come with a multi-channel capability. Should a new connected speech device appear on the market soon, it certainly would be investigated carefully for its applicability to the team training problem.
c. A text-to-speech voice generation system. Votrax has recently marketed such a device, and others may soon follow suit.
d. A speech replay system designed to produce speech from digital data stored on disk. This facility would be instrumental in giving individualized voices to the simulated ASW support personnel. Quite recently, a number of systems have become available which claim to support good quality reproduction of digitally recorded speech at reasonable bit rates. It would be desirable for this device to have a recording capability as well to simplify the speech encoding process.
e. A multi-channel tape recorder capable of recording 8 to 16 tracks of speech, capable of operating under computer control, and capable of putting event markers on tape on computer command. The ability to record a reasonably large number of tracks is needed so that each trainee's speech and each model's speech can be recorded separately. The instructor may also wish to record comments for later replay or use by the researcher.
f. A line printer capable of supporting at least a medium resolution plotting package.
g. Four system CRTs to support development and maintenance of the system.
h. Disk unit for each computer, capable of storing at least 50 Megabytes.
i. Magnetic tape unit to support system development, and to facilitate storage of significant amounts of research data and training records.
j. Three student consoles with basically the same physical appearance. Each console consists of one raster-scan display unit, a keyboard, a communication panel for microphone plugs, volume control knob, voice level meter, and circuit switches; as well as a capacitor touch-button panel, similar to that shown previously in Figure 6. The console must also have a track ball and track ball related function

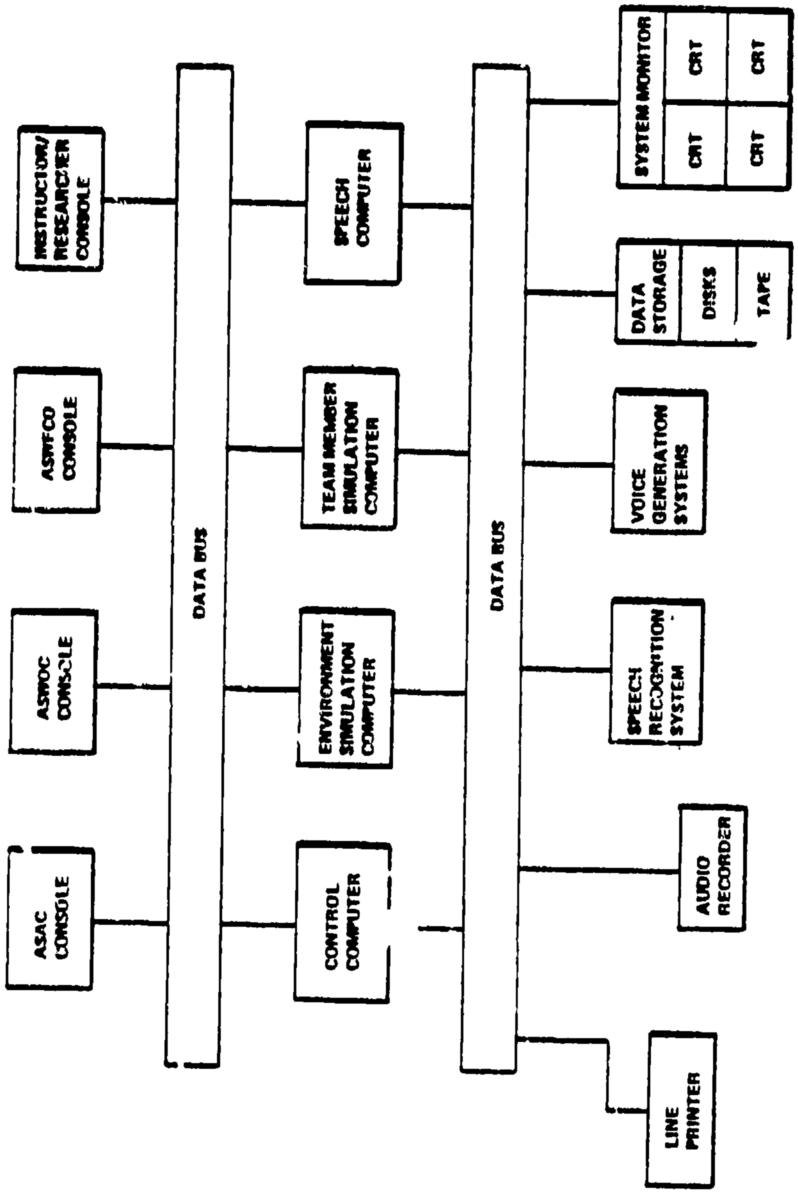


Figure 8. Basic system architecture.

keys. One of the three display units (the ASWOC's) should be a color unit. The other two can be monochromatic.

k. One instructor/researcher console having the same basic shape as the student consoles but with the screen tilted more toward the horizontal. This console should provide a capability for the instructor or researcher to monitor any communication circuit, and to reproduce at his own display the entire contents of any one of the team member's displays.

The equipment suite described here represents an estimate of hardware required to support the entire system concept. A section VII of this report addresses the possibility of a staged approach to system construction. The full system as described in this section would be the end product of the Stage 3 implementation. The subsets of equipment needed to support Stages 1 and 2 are sketched in Figures 9 and 10, respectively.

WHAT WILL THE SYSTEM DO?

Having described the team training demonstration system from the perspective of an observer, consider now the internal processing which is required to support system operation. In the first place, a number of ASW support personnel must be modeled, including the SAU commander, assist ship personnel, air support persons, sonar officer, bridge, surface watch officer, and plotters. The environmental simulations include the basic physical environment, motion models, weapons, sonar, radar, magnetic anomaly detection, and visual detection. A model of the enemy will simulate the hostile unit's behavior, capabilities, and motion.

In addition to this bulk of basically supporting simulation, team member simulation is required. The team training demonstration system must be capable of operating when any (or all) of the human team members are absent. Specific requirements which arise from this are described in Section VI, System Requirements. This point implies that there is a computer model of each team member which is capable of operating in place of its human counterpart. The team members can serve three additional functions: to provide information for on-line feedback to the human team member, to create a yardstick for performance measurement to use in evaluating the human team member's action, and as an aid for the automated speech understanding system to provide reasonable predictions about what a given team member might say next.

Next, communications capabilities are required. The system concept is centered around communications among team members and between individual team members and simulated support personnel. A significant part of this communication is verbal, so the system must have the ability to understand what is spoken by the team members, to act based upon that understanding, and to generate simulated verbal responses or initiate verbal communications as necessary to support the total simulation. More broadly, the system must monitor verbal or console-to-console communications between any team member and any real or simulated target of the communication effort. Furthermore,

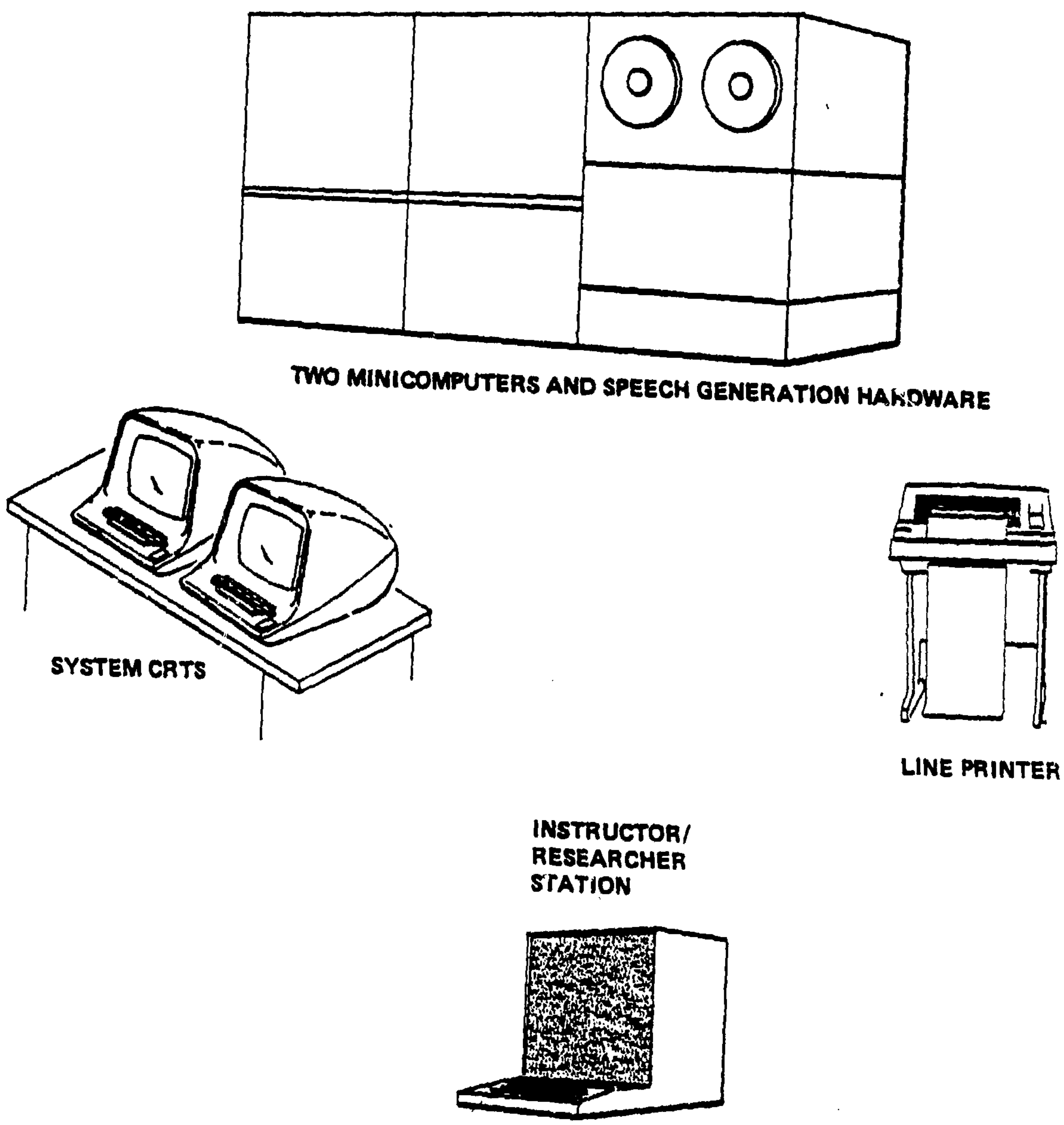


Figure 9. Stage 1 developmental system.

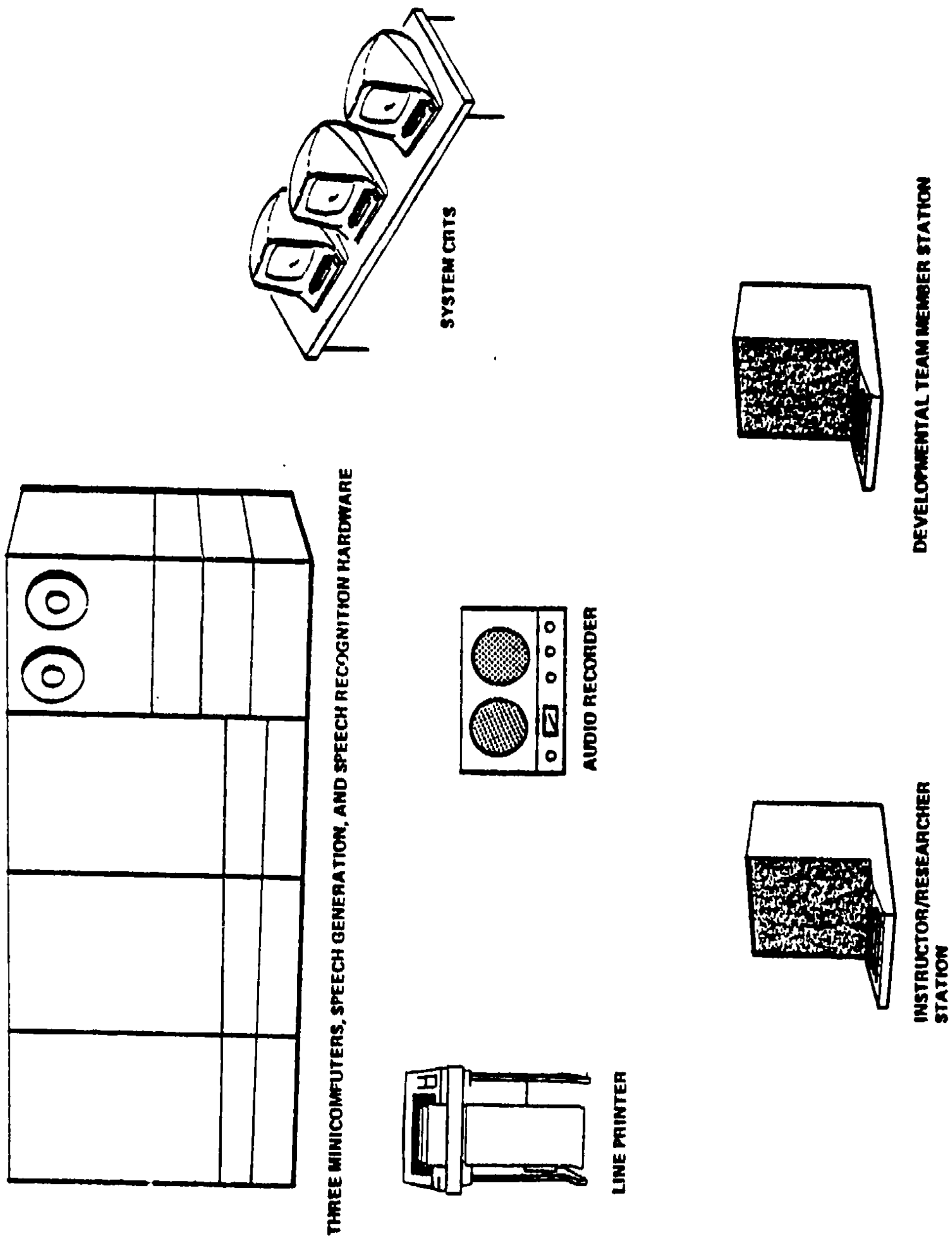


Figure 10. Stage 2 developmental system.

the system must simulate appropriate responses to these communications and initiate communications when that is appropriate. Finally, to aid the analysis of communications after the fact by the researcher, the system must maintain annotated records of all console-to-console and understood verbal communications as well as record regular time tags on one channel of the audio tape so that the system's records can be correlated with the audio recording.

The system must be capable of a limited kind of active instruction - enough to teach the team members how to use the consoles, how to handle the communications system, how to facilitate speech recognition, and how to ask for help. This capability will also be employed to give detailed instructions to the team members during reference pattern collection and validation.

A sophisticated and flexible performance measurement system is required which is capable of trying out many different varieties of candidate measures for effective team performance. To assess each individual team member's contribution to overall team performance, the performance measurement subsystems will track each individual's actions and evaluate individual strengths and weaknesses. Since much of the effort in building good performance measures will be based on data gathered by the system, the system will provide detailed record keeping and will preserve data in standard formats for use by other off-line analysis and data reduction programs.

Feedback is an important issue for team training, and this system will offer a variety of means for providing feedback. The ASWOC's console, for example, allows the researcher to explore the use of color graphics to provide feedback and information beyond that which an ordinary operational console provides. Furthermore, the system must be capable of providing effective <u>positive</u> feedback, a capability which is absent in most automated training systems. The capabilities furnished by sophisticated team member models make the process of providing feedback - positive, qualified, or negative - much easier.

(The careful reader will notice a function in Figure 6 denoted "Sigh!" Why "Sigh!"? The apparently facetious console function named Sigh! is not at all intended to be flippant. Instead, it should provide a kind of pressure-release valve for the trainee when he finds that he is fighting the system, being misunderstood by the speech misunderstanding software, or generally having a bad time. The function of Sigh! is to offer an opening for student initiative in giving feedback to the system: "You don't understand me," "you don't respond to what I say," or "you're driving me crazy." Our experience with the automated training systems leads us to believe that the trainee occasionally becomes very frustrated and often has no acceptable way to deal with the frustration. The Sigh! function lets the trainee talk back. Of course, "Sigh!" is not intended to be the sole interactive mode for the system. The function of "Sigh!" is to offer the user a capability for quick reaction to the system <u>while an exercise is in progress</u>, and to initiate detailed recording of the circumstances which produced the user's reaction. When just one team member is involved, the Sigh! function could freeze the exercise

and initiate a more prolonged interactive sequence. In this event, the Sigh! function would act principally as a device to freeze the problem action and to call up a full-scale menu for interaction.)

The system must also allow for certain kinds of controlled team training experimentation. For example, the influence of one particularly weak team member could be explored fairly carefully. Using an ASAC model with controlled pieces of misinformation or lack of knowledge can allow the researcher to see how team performance degrades as one individual's (the ASAC's) performance degrades. This system will also provide the facility to support a weak human team member by providing him with individually tailored prompting messages. In this way, team performance can be observed while a weak team member is being compensated for.

The team training demonstration system will also provide the capability to explore the adaptive component of training in a variety of ways. The enhancement or degradation of team member performance, described above, could also serve as an adaptive variable. Other dimensions of adaptation will change the environment. Some possibilities include modifying the sonar dispersion exponent and influencing the range at which sonar contacts can be gained; modification of the wind or sea state which affects sonar similarly; making the submarine faster or slower, more or less evasive; increasing or decreasing the number of supporting aircraft; controlling the number and kinds of weapons available.

In summary, the team training demonstration system will be supported by a simulation system with several component subsystems. It is designed to monitor, control, and simulate communications between a team member and any other real or simulated member of the full ASW crew. In support of this communications control facility, there will be a state-of-the-art speech recognition system, a text-to-speech voice generation system, a digital voice generation system coming from the newest technology, a computer-controlled multi-channel tape recorder, and sophisticated software to use these devices to their fullest capabilities. The system is also designed to evaluate a range of proposed performance measurement tools, to permit new kinds of performance measurement techniques, and to explore some of the adaptive components of team training.

SECTION V

TECHNOLOGICAL RESEARCH ISSUES

The team training demonstration system whose functional description is presented on these pages must be considered, in the broad context of training system technologies, as a system which has both hybrid and transitional aspects. The system is hybrid in that both traditional and less traditional approaches are called upon, often in the same subsystem. Below we describe a simulation subsystem which employs both traditional and non-traditional approaches to the various simulation problems. The speech generation system design is also a hybrid of old and new: well known technologies employing generation of canned phrases are called for, as well as newer techniques to construct phrases dynamically, as the need arises. Furthermore, traditional modes of performance measurement will be called upon, yet the team training environment seems to call for a smarter mode of performance measurement, like that a good human instructor could provide.

The system being described is also very much transitional. It is not a traditional automated training system, nor is it avant-garde. It maximizes the exposure of some new techniques and new technologies which show high potential for the team training environment, yet minimizes the technical risks associated with the relatively new and as yet unproven. In the sections which follow, we discuss four areas of interest for the development of technological tools to support team training systems. In particular, we address those specific technological issues which this ASW team training demonstration system should be able to examine in some detail.

SIMULATION

The team training demonstration system shall utilize traditional modeling techniques for all simulation subsystems which are not concerned with the modeling of team member functions. In addition, the system which is described on these pages shall be capable of modeling the functions of ASWOC, ASAC, and ASWFCO to a degree of fidelity sufficient to allow each team member model to substitute, in a training setting, for the corresponding missing human team member. This requirement calls for a qualitatively more sophisticated approach to modeling, inasmuch as complex human behavior is involved in a dynamically changing environment where there is a large range of potential acceptable actions.

The principal technological issues involved here are how well this can be done, and what techniques are appropriate to do it. Simulations like the modeling of missing team members are knowledge-intensive, as opposed to number or data intensive. Since "chunks" of knowledge are the raw material of this kind of simulation, means must be found to represent this knowledge adequately, to manipulate it in order to generate conclusions and decisions about actions to be taken, and to control the process by which "old" knowledge is used to generate "new" knowledge and decisions. In the past ten years,

several systems designed to work at the knowledge engineering level have been built and they show great potential. (A few of them are described later in the section dealing with system simulation design considerations.) A fundamental issue here is how good a knowledge-based system can be built which will function in real-time on available small scale computer systems.

SPEECH UNDERSTANDING

The speech understanding subsystem, which is described later, must handle the problem of understanding connected speech for three speakers at the same time, in an environment which is ordinarily characterized by a large number of relatively unstructured communications. An obvious initial approach to this problem is to enforce some stylization of speech (basically standardization) and to inhibit "unnecessary" collateral conversation. A difficult enough problem remains even if this assumption is made. If the more natural unrestrained speech of a normal CIC were to be allowed, the speech understanding problem would become much more severe. One significant reason why the scope of the ASW problem was restricted as it was is because of the present day limitations of speech recognition systems. To move in the direction of permitting a large volume of relatively unrestrained communications, advances in recognition devices and speech understanding software are essential. Were the technology available, the functional description of the speech understanding subsystem would call for a hybrid speech recognition system which was in part a key word spotter and in part a connected speech recognizer. The key word spotter would look through incoming speech for key words or phrases. When such a word or phrase was found, the connected speech recognition process would come into play, recognizing "relevant" speech which the word spotter had located. In this way, speech which was determined to be significant could be extracted and understood, while other speech could be ignored. This would permit, in principle, a relatively unconstrained speech environment and a big vocabulary.

Since hybrid speech technologies like the one just described don't exist yet, perhaps a parallel effort to develop the technology is needed. It is the case, however, that a more artificial speech environment must be tolerated if speech is to be used at all at the present time. But significant questions remain: How well can speech understanding be done for three people at the same time in this more constrained environment? How might word spotting techniques be employed to push toward a less constrained environment? How can other system knowledge sources be used to aid the understanding process, particularly by enhancing the ability to predict what <u>might</u> be said under a given set of circumstances.

SPEECH SYNTHESIS

Since techniques for speech synthesis and speech replay have been available for some years now, there is a tendency to take good synthesized speech for granted. To a certain degree, this is fair: Votrax, for example, is now available on a single chip for a low price. But good quality, human-sounding

speech is harder to get. Digital storage and reconstruction of speech at reasonable bit rates are possible, but the quality of speech has thus far been disappointing, large disk storage requirements still remain, and the standard techniques for piecing together strings of individually recorded items sometimes produce unacceptably choppy speech. There are chips available with linear predictive coding (LPC) encoded speech for replay, but the chips require an expensive custom fitting for specialized vocabularies.

In addition to these problems just with producing good quality speech, there is another question. Succinctly stated: What should be said?

To convey information to a human being as another human being might, the system must call upon its knowledge of the subject matter, of the intended listener, of the importance of the communication, and of the syntax of English to put the information into words and create fluid speech. Processes which are automatic in human beings as they marshall information and choose words to communicate must somehow be recreated or simulated by the speech generation system when it "decides" what is to be said. How it should be said is another question. Most, if not all, existing automated training systems which use speech generation rely on the reproduction of canned phrases - phrases which have previously been built in digital form, or phrases whose constituent phonemes have been selected and entered in text files. In an environment like the CIC during an ASW exercise, a large number of event sequences are possible, and the speech generation capability should accommodate the production of phrases for all eventualities. This suggests strongly that some kind of text-to-speech system (such as the one recently introduced by Votrax) would be indispensable in supporting the voice synthesis aspects of simulation. To create phrases dynamically, the simulation subsystem must be smart enough to know what to say. That is, it should have the capability to use the information available to it in order to make these decisions: what to say, when to say it, and to whom to say it.

There is also a peripheral issue, straddling the boundary between training and technological research questions. Since there are quite a number of personnel in the ASW environment whose voices must be simulated, the speech generation subsystem must produce different voices. How many distinct voices are adequate for the task? Using a single Votrax for all the voices would probably produce unacceptable confusion, but how many like-sounding voices can be tolerated?

PERFORMANCE MEASUREMENT

Another group of research issues which are implicitly involved in the design of the team training demonstration system concern performance measurement (PM). Performance measurement is usually considered the province of the training analyst, but there are several PM issues which impinge on the area of software technology.

The scope of PM is often taken to be limited to the process of monitoring events which occur in the training exercise and to the activity of correlating collections of combinations of measurements taken with respect to these events. Certainly data of this kind should have a significant bearing on the evaluation of a student's performance, but the impartial observer may feel that something is being missed in this process and that, in a certain sense, the forest is overlooked in favor of the trees. The presence in the proposed system of computer models of competent team members offers an opportunity for evaluation of a human team member's performance from a broader point of view. The ideal of an extremely patient and fully knowledgeable instructor could be realized in a knowledge-based system. With such a system one could create a capability for understanding something of what a team member is really trying to do and of uncovering the faulty conceptual notions underlying less than optimal team behavior.

Another performance measurement issue has particularly significant ramifications for software design and system integration. How do system designers and programmers implement the performance measurement system which the training analyst recommends? In the past this has been a sore point. Often, PM systems have required coding the same knowledge about a training situation in a dozen or more different places. Occasionally, this knowledge-coding process is not entirely consistent, and the inconsistencies must be discovered, then painstakingly resolved and corrected. Furthermore, because PM is usually overlayed on the other subsystems, nearly all the other software must be debugged before PM can be tested. This means that one of the most important instructional system features is debugged only at the end of the testing process, and rarely can enough time be spent to see that PM software lives up to the training analyst's original conception. Then, too, there is the PM domino effect: Failing one PM minitest early in an exercise can, because of an otherwise quite reasonable design, cascade to produce failures of all succeeding PM minitests, no matter what the student does.

The performance measurement system should really be smarter than all this. Most of the difficulties just described could be overcome if the PM system had access to an organized knowledge base in which knowledge could be consistently and irredundantly represented both for system use and for appraisal by the training analyst.

SECTION VI

SYSTEM REQUIREMENTS

An automated training system is a complex entity with many interacting capabilities. Figure 12 provides a simple illustration of this point. It suggests that there is a core of knowledge upon which primary system capabilities rest, and furthermore that there are many other capabilities which can be added to embellish the outward aspect of such a system. Not all of these embellishments are appropriate to add to a research device, however, and the following discussions describe which aspects are important to the successful demonstration of the concept, and specify their functional requirements.

SIMULATION REQUIREMENTS

To support an investigation of team training issues in a Combat Information Center involved in an ASW mission, a simulation of the tactical environment as it would be seen by the team members shall be provided. This simulation shall be reasonably faithful to real-life, and it shall also attend to the degrees of relevance of various environmental stimuli as they affect the team members. For example, sonar data are important elements in decisions which the ASWOC makes. But only a <u>processed</u> version of these data is required by him: he needs only an indication of the strength of the contact, together with the bearing and the range, if they are available. The raw "pings" are essentially irrelevant to him.

What is the function of simulation? Simulation is basically imitation: the simulation under discussion here consists of software (and, to some extent, hardware) which imitates or mimics either <u>something</u> in the real world (the physics of sonar or radar or magnetic anomaly detection; an operational console, the dead-reckoning table, etc.) or <u>someone</u> in the real world (SAU commander, sonar operator, helicopter personnel, etc.). The simulation must be directed foremost by the functional requirements which the system places on it. Thus the end products of the various simulation subsystems are most significant and the processes which yield those end products are less important. The fidelity which is required of the various simulation subsystems is not an easy issue to pin down, and perhaps it is best approached negatively. No simulation should produce a result which is substantively at odds with the real behavior of what is being simulated. Furthermore, no simulation should alienate the team members, in the sense of repeatedly injecting forceful reminders that the tactical situation is synthetic. The literature of team training is inconclusive insofar as insights into the necessary fidelity of simulation for effective training are concerned. Perhaps the best guideline for the system designer to follow is a rule of thumb which says that, within the constraints of system pragmatics and driven by system requirements, the simulation subsystems should aspire to operational transparency: as much as possible, the output of each simulation should be indistinguishable from its real-life counterpart.

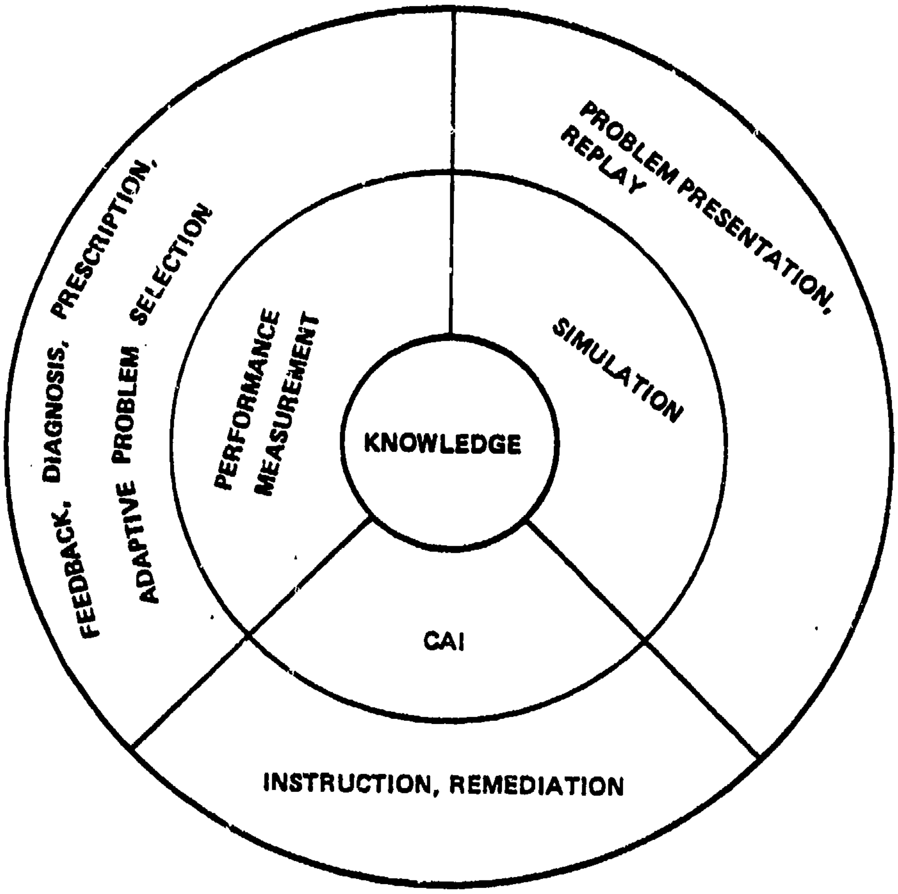


Figure 11. Components of an automated training system.

The simulations which are required by the team training demonstration system are enumerated below. For each simulation subsystem, a top level description of its functional requirements is given. Broadly speaking, the simulation subsystems can be divided into two general groups: team member simulations, and all the remaining. "All the remaining" includes all the required tactical environment simulations such as physical environment, detection, weapons, platform motion, and supporting personnel. These tactical environment simulations are taken up first. Then the simulations of team members are described. The general approach has been to make the tactical environment simulations good enough to seem reasonably realistic, but as simple as possible. The team member simulations will be considerably more complex.

One issue of terminology should be dealt with here. At times, a given simulation subsystem is referred to as a "model." The word "model" is to be understood to mean a representation of an existing object, process, or person by mathematical formulae or other software. We do not intend the word to mean a person or object serving as an example to be imitated or compared with. This distinction must be made because the team member models will indeed function, in some sense, as exemplars, and confusion of these two senses of the word "model" must be avoided.

THE SYNTHETIC TACTICAL ENVIRONMENT

Several models are required to create a credible simulated tactical environment. Those elements of the tactical environment which must be modeled include the outside physical environment, the motion of surface, subsurface, and air platforms, the capabilities of the various ASW weapons systems, the detection subsystems available to the ASW team, and enemy maneuvers and tactics. Each of these is discussed in greater detail below.

PHYSICAL ENVIRONMENT MODEL. This simulation subsystem will essentially be static and non-evolving. Its function is to provide a limited representation of a simulated outside world for the benefit of the other simulation models. The principal features of the ASW physical environment which will be represented are wind, ocean state, ocean thermal profile, visibility, and weather state. Wind and ocean conditions are the most important among these. Wind will be maintained as a number on the Beaufort scale, and sea state will be recorded as well as the presence and location of pertinent ocean thermal layers All the physical state variables shall be capable of being set by the instructor at the beginning of an exercise and shall remain constant throughout a given exercise.

PLATFORM MOTION MODELS. The motion model simulation subsystem must be devoted just to the job of moving the air, surface and subsurface tracks which are involved in the problem in accordance with their particular dynamic properties. This subsystem maintains motion model minimum, maximum, and nominal values for motion parameters such as speed and acceleration. It also holds turning parameters for surface and subsurface tracks. These parameters include advance and transfer. The motion model module also contains the dynamical equations

required to update the position, heading, and speed of all the tracks. Since the geographic scope of the tactical problem area is relatively small, the tactical arena will be modeled as a plane, and all positions of tracks will be reported in coordinates (x, y, z) relative to this plane. The x- and y- coordinates measure displacements in this plane relative to a fixed origin, and the z- coordinate represents the height above or depth below this plane.

The equations of dynamics in this module shall permit realistic smooth changes in speed and heading simultaneously, and shall admit cumulative errors in position no greater than 50 yards in 30 minutes of exercise time.

Motion model data for the following kinds of tracks must be maintained by this module: destroyers (DD-963), fixed wing aircraft (P3), LAMPS helicopters, and diesel-electric submarines.

WEAPONS MODELS. The weapons capabilities of the ASW attack force will be simulated by the weapons control module. This module will simulate at least torpedo and ASROC type weapons, including the numbers available, the dynamics, the search pattern settings (where appropriate), the maximum effective ranges, and the dependence on ocean conditions. This module must also admit a probability model for determining the consequences of a given weapons launching in terms of a damage/destruction evaluation for the target (and, for that matter, for any friendly tracks in the vicinity). The weapon types and numbers available to the ASW team should be amenable to instructor control at problem set-up time. For those weapons for which it is appropriate, the search setting shall be capable of being set on command by a team member. This module shall be designed and created flexibly enough so that additional weapon capabilities could be added without a significant re-design effort.

DETECTION MODELS. Several detection simulation modules are required to model the action of the various detection capabilities of the ASW ship and supporting aircraft. These detection capabilities include active, passive, and dipped sonar, as well as magnetic anomaly detection, radar, and visual detection.

Sonar. The most highly developed of the detection models must be those for sonar, inasmuch as sonar is the single most significant tool of detection in the ASW arena. Sonar shall be modeled by means of the standard sonar equations for active and passive sonar which are used to calibrate operational sonar systems. Furthermore, the sonar models shall take into account noise from the baffles, the baffle angle, and ocean turbulence (knuckles) created by turns. The object of this additional sophistication is to simulate realistically the diminution or loss of sonar return when the ship's maneuvers inhibit effective use of the sonar. The output of the sonar system shall be a number indicating strength of contact, together with the bearing of that contact for passive sonar, and bearing and range for active sonar. Doppler shift information (up, down, no Doppler) shall also be produced by the sonar model.

Magnetic Anomaly Detection. The magnetic anomaly detection (MAD) simulation subsystem shall be capable of modeling the action of an airborne MAD device in the short-range, low altitude search for local disturbances in the earth's magnetic field produced by a submarine and the process by which this disturbance can be detected. Environmental variables, especially sea state, shall be taken into account by this model. The output of the MAD module will be anomaly detected, range and bearing, or no detection.

Radar. The radar simulation subsystem shall function principally to model the radar location of friendly air and surface vessels in the ASW force. It shall have the additional peripheral function of modeling radar returns from a submarine or its periscope should the submarine be operating at or near the ocean surface and within radar range. The radar model shall be capable of simulating the effect of rain and other weather on radar ranges. The output of this module shall be positions for all tracks (friendly and hostile) which are within the effective radar range.

Visual Detection. Detection of tracks by ordinary visual sighting shall also be simulated to the degree required to produce reports of visual submarine sightings by air or surface tracks when a submarine would realistically be seen. Also, the visual detection model shall be called upon to determine area-clear information for the bridge model.

ENEMY MODEL. The enemy shall be represented by one submarine, and the enemy simulation subsystem shall be capable of expanding to include at least two submarines. The primary concern initially should be to create a model of one conventional diesel electric submarine with limited intelligence. This model should be capable of pursuing a course toward a specified destination and should be able, if the instructor chooses, to pursue an evasive approach when in danger of attack. It follows that the submarine model should have the capability of detecting an ASW ship using passive sonar. The enemy model shall be designed to allow expansion of the submarine's intelligence as well as to permit broadening of the submarine's capabilities vis-a-vis dynamics, weapons, and detection. The design should be flexible enough to allow incorporation of independent work on the modeling of intelligent adversaries, even though the intelligence of the initial enemy model will be rather limited.

MODELS OF ASW SUPPORT PERSONNEL

Because the ASW team consisting of ASWOC, ASWFCO, and ASAC is not an isolated entity but rather a subteam of a larger group engaged in ASW, the simulated combat environment with which the subteam interacts must include adequate models of support personnel to simulate a full ASW group. The support personnel who are relevant include ownship personnel (bridge, plotters, surface watch officer, sonar operator) assist ship personnel, supporting aircraft personnel, and the search and attack unit (SAU) commander. The support personnel simulation subsystems shall model those aspects of the behavior of ASW group members which impinge directly on the ASWOC, the ASWFCO, or the ASAC in the course of the ASW exercise. In particular, communications by support personnel

to any of these team members must be simulated, both with respect to form (actual speech to be generated, or button action to be simulated) and content (what is spoken, what information is transferred by button action). Furthermore, decisions made and actions taken by the support personnel must be simulated insofar as they influence either further actions, decisions, or communications by the team members or the general course of the ASW problem.

The more general comments in an earlier section about simulation in general apply here, too. The output of these support personnel simulation modules is the most significant element; the means by which the output is derived is less important. For example, the model of bridge personnel need only simulate communications made by bridge personnel to team members and responses to team member communications (in terms of both producing simulated spoken acknowledgments and causing changes in the ship's simulated speed, heading, etc). A detailed model of bridge operations is thus not appropriate.

In several cases, these models of supporting personnel are not models of individual persons, but instead represent collective models of persons engaged in one area of the technical arena. A single model of all the assist ship personnel is adequate, for example, and no further distinction or breakdown of functions is necessary. In the case of each of the supporting personnel models, it is most important that that model initiate communications at appropriate times which are correct both in form and content, and that the model respond appropriately to the actions and communications of each of the team members. In the sections which follow, each supporting personnel model is taken up and discussed briefly.

BRIDGE MODEL. The simulation of ownship bridge personnel shall model all appropriate communications from the bridge to the team members, whether such communication is a response to a team member or is initiated by the bridge. Furthermore, the bridge model will respond in a realistic fashion to ASWOC or ASWFCO requests for changes in the ship's course and speed. The bridge model is also responsible for generating an area-clear message before a weapon is fired.

SONAR OPERATOR. There shall be a model of a capable sonar operator which simulates all relevant communications from the sonar section to the team members, whether such communications are responses to team member communications or are initiated by sonar personnel. The sonar operator model shall report the output of the physical sonar model and the status of sonar in a timely manner to the ASWFCO.

ASSIST SHIP PERSONNEL. The model of assist ship personnel shall simulate all appropriate communications from the assist ship to any of the team members, including reports of sonar contact and directions for ship motion. The assist ship model shall also be responsible of producing course and speed changes which are required. This simulation subsystem must also model responses to team member communications and must model communications which are ordinarily initiated by assist ship personnel.

AIRCRAFT PERSONNEL. Collective models of aircraft personnel are required for the following aircraft: fixed wing aircraft (P3) and LAMPS helicopters. Each model must simulate communications with team members which are realistic in form and content. In particular, magnetic anomoly detection (MAD) reports, sonar, radar, and visual contacts with the enemy submarine shall be simulated. Responses to directions issued by the ASAC shall be made both by appropriate simulated aircraft motion and by simulated speech.

SEARCH AND ATTACK UNIT COMMANDER. The simulation of the SAU commander shall model the SAU commander's supervisory role: this simulation subsystem shall be capable of responding to the ASWOC's communications and requests for permission to take various actions. This model shall also have the capability to initiate communications so as to be able, for example, to countermand decisions of the ASWOC. The SAU commander model shall also be responsible for generating reports to the ASWOC regarding ship formation, the assignment of search sectors, the choice of a search plan, and required course and speed changes.

PLOTTERS. Simulation of the plotters at the dead-reckoning tracer shall provide the capability for confirming the cone of courses and limiting lines of approach information.

SURFACE WATCH OFFICER. The surface watch officer model shall have the capability to determine courses for a zig-zag approach and shall also have the duty of generating an area-clear message before a weapon is fired.

MODELS OF THE TEAM MEMBERS

Perhaps the principal item which makes the proposed team training demonstration system unique, aside from its obvious direction toward teams instead of individuals, is that it shall provide a simulation of each team member with a fidelity sufficient to allow the computer models to function in the absence of the corresponding team members.

This notion of "simulating missing team members" is not taken lightly. A number of issues - ranging from cognitive psychology to software design - are involved just in developing an approach to the problem. How shall the full range of knowledge, experience, and intuition of a human team member be modeled? Is it possible?

A CONCEPTION OF THE PROBLEM. Let us begin with an admittedly terribly simplistic view of a human being. A human being, in this conception, is a kind of "black box" processor which accepts inputs from the world using the conventional human sense organs, and which produces outputs in both verbal and haptic (button pushing) form. Internal to this black box processor is a variety of processing activities, some of which we can infer (for example, by introspection) and some of which we can mimic without necessarily understanding the details. We know that this black box is equipped with a memory and consequently is capable of basing its activities on past experiences. Beyond this, we realize that the black box is by no means a simple logic engine

and that its means of arriving at decisions and taking action are based on deduction, intuition, expectation, emotion, and much else that is not well understood.

In the constrained world of the CIC during ASW activities, the team members - ASWOC, ASWFCO, and ASAC - must possess the specialized knowledge needed to function at their jobs in the tactical ASW environment. Beyond this specialized information, human beings bring to these three tasks certain other kinds of more general knowledge - among other things: common sense, basic information about how the world works, and intuition developed through experience. In order to make simulations of the team members operational and credible, the models must address not only basic knowledge about tactics and team coordination but must also include basic kinds of common sense and experimental understanding. An ASWOC model which "knows" the basic tactical rules for pursuing a submarine but does not know that a DD-963 is constrained to move on the surface of the ocean would not be worth much.

WHAT THE SIMULATION SHALL DO. The goal of the team member simulation system shall be to model the tactical and the common sense knowledge required of the ASWOC, the ASWFCO, and the ASAC in such a manner that the computer models shall be able to function in place of a human team member who is absent, and such that each model's performance is qualitatively like that of its human counterpart.

A general outline of the functional requirements of the team member models is provided in the paragraphs which follow. More specific details about the functions of the ASWOC model are provided in Appendix 1.

The ASWOC Model. The simulation of the ASWOC shall model the ASWOC's activities in using the tools at his disposal to pursue, to search for, and to localize a submarine. In a timely manner, the model shall compose and send to the speech generation software all those messages appropriate to the current tactical situation. The model shall also initiate appropriate button action communications. Beyond this, by virtue of the speech understanding software, the ASWOC shall respond to properly framed communications from human team members, to computer-generated communications from ASW support personnel simulation software, and to console-to-console communications from human team members or simulated support personnel. When the tactical situation calls for it, the ASWOC model shall be capable of making competent context dependent decisions and of taking appropriate action and making appropriate commands to implement its decisions.

The ASWFCO Model. The ASWFCO model shall be capable of understanding and generating the same kinds of communications as the ASWOC, although the total volume of communications involving the ASWFCO is considerably smaller. Beyond these communication capabilities, the ASWFCO model shall be principally responsible for the preparation and launching of weapons, for coordinating the

solution of the fire control problem, and for the determination of water entry point and weapon danger areas. The ASWFCO model shall also be responsible for monitoring simulated sonar reports.

Provision shall also be made in the ASWFCO model for the ASWFCO model to take over the attack from the ASWOC or ASWOC model.

The ASAC Model. The ASAC model shall have the same general kind of communication capabilities as the ASWOC and ASWFCO models. In addition, the ASAC model shall have the capability to direct ASW aircraft in the localization and tracking of a submarine, as well as ASW air weapons control. The principal responsibility of the ASAC model shall be to communicate the ASWOC's commands and other relevant tactical information to the aircraft and to relay aircraft status and tactical data to the ASWOC.

AN APPROACH TO THE PROBLEM. What approach should be taken in implementing these team member simulations? From an examination of small pieces of the whole team member simulation problem what has emerged has been a considered judgment that a so-called "knowledge-based" simulation is called for to satisfy the many demands we have placed on these models. A recommended form for this knowledge-based simulation is yet to be determined pending a most careful scrutiny of the knowledge used by each team member in an ASW problem like the one described in our scenario. Tentatively, our recommendation would be to use a generalized production rule system such as is described in Appendix I.

Characteristic features which the general knowledge representation structure must have are:

a. strong compatibility with the kinds of knowledge present in a tactical environment like the ASW CIC,
b. capabilities to admit meta-knowledge for control, so models can know the extent of their knowledge, and
c. potential to incorporate, in addition to basic knowledge relevant to the tactical situation, special kinds of instructional and performance measurement knowledge.

A preliminary design for a knowledge-based ASWOC model is included as Appendix I of this report.

EVENT DETECTION REQUIREMENTS

An event detection capability is required to enable the system to "know" what is happening during training. This capability shall be distributed among a number of procedures, each designed to monitor and interpret data from a particular information channel. These individual procedures must format information and send it to the centralized message routing mechanism for distribution to the applications procedures. Thus, for example, when the speech understanding capability detects that the ASWOC has spoken and has determined the meaning of the communication, it must formulate a message

consisting of a unique identification number which specifies that the message contains an ASWOC speech communication, the channel on which the communication was transmitted, the time the communication occurred, and the content of the communication. It must then forward the message to the centralized message routing mechanism which will in turn determine the set of procedures and models which are to receive the message, send it to each, and record the message for subsequent analysis.

Events can be classified as simple or compound. Simple events correspond to single events in the simulated world such as the utterance of a particular verbal communication by a person or model, or the sonar detection of a submarine. Compound events are defined through Boolean operations upon simple events and/or state information. An example of a compound event would be the ship's entering the torpedo danger area (TDA).

It is important to note that although information which is needed to detect trainee errors is included in the list of events, trainee errors as such are not included. This reflects what is regarded as an important design goal: centralization of the performance measurement capability. All decisions about the adequacy of trainee performance must be the work of a centralized procedure. If the performance measurement rules are embedded in diverse event detection modules, not only are they more difficult to change but it is more difficult to take special circumstances into account when evaluating performance.

PERFORMANCE MEASUREMENT

The provision of automated performance measurement means, in the team training context, the provision of the capability to interpret events in the training environment and to evaluate trainee and team responses and decisions. The data generated by this function must be suitable for supporting:

- on-line feedback to individuals
- on-line feedback to the team
- post-run debriefing of individuals
- post-run debriefing of the team
- qualitative performance assessment for instructor use
- record keeping
- adaptive problem selection
- diagnosis, prescription, remediation
- statistical analysis and norm development

While not all of these features will be provided in the first stage implementation (e.g., diagnosis, etc.), it is nonetheless important to recognize all of these potential uses when specifying the functional requirements of the performance measurement capability.

A variety of performance measurement-related functions will be needed in order to provide outputs suitable for these diverse needs. These are discussed in the paragraphs which follow.

ERROR DETECTION. There is a class of errors of omission and commission which can be defined, a priori, as being wrong. The performance measurement system must be capable of detecting and reporting errors of this class. It is important that this capability be flexible and easily enlarged and modified, because it is inevitable that old rules will change and new rules will continue to be articulated.

QUALITATIVE PERFORMANCE EVALUATION. Error reports, in themselves, do not provide sufficient information for performance evaluation. In particular, the instructor needs an overall assessment of the quality of team performance, and the system itself needs a measure by which to adaptively scale the difficulty of succeeding problems. In early development work, this qualitative evaluation can take the form of an average of weighted error scores. In time, as performance data are collected, statistical techniques can be employed to identify factors relevant to good performance and the contribution of the various measures to the estimate of those factors. This information can then be incorporated in the automated scoring algorithm.

Problem Areas in Evaluation of Team Performance. The ASW team training context provides special challenges to the designer of a performance measurement and evaluation system. In the first place, the simple enumeration of error events for the three individuals and the team becomes exceedingly complex in an emergent situation. Then too, the specification of tolerances for each error condition is difficult. The design and implementation of modules to perform the evaluation is laborious and represents at least a duplicate implementation of the performance rules. Just to obtain consistency between the various implementations is no small task. An example may clarify the point. Suppose the following rule is extracted from the expert, "Person P shall perform action A within a safe period of time from event E." Suppose further that the expert is pressed until he defines, "a safe period of time" to be "within 10 seconds." Using a traditional approach, this rule is embedded in the model of person P in such a way that the model is constructed to detect E and perform A in, say, five seconds. The rule is coded again in the performance measurement logic in a slightly different form. Perhaps when E occurs it will schedule an omission check procedure in 10 + 2 seconds (giving the trainee a fudge factor) which will determine whether A occurred within the appropriate time frame. (Of course, there are many other ways to do this - the point is, though, that the requirements of the performance measurement process are slightly different from those of the model team member process.) The rule must be coded a third time to provide feedback about the error to the trainee, and will probably take the form of the English sentence, "You failed to take action A within 10 seconds of event E." If computer aided instruction (CAI) is provided, the rule will end up being coded at least once or twice more in the instructional materials as well.

Suppose all of this has been done. It is inevitable that once the system is working, it will be discovered that a safe period of time does not equal 10 seconds. No matter how "table driven" the system is, the difficulty involved in getting the change implemented should be obvious.

Another problem which will arise with equal inevitablity is that there will be times when the trainee is unable to perform the required action because he is required to perform some other, more important, action. It is difficult to predict all of the possible conflicts of this sort in advance and to take them into consideration in the automated performance monitoring capability.

Finally, the method has the profound shortcoming of being unsuitable for generating positive feedback. The best that can be said is that the trainee made no errors.

A Different Approach. There is a different approach to performance measurement which may enable the problems described above to be surmounted more gracefully and effectively than with the traditional approach. In fact, one of the primary reasons for proposing a knowledge-based approach to solve the team training problem was precisely to accommodate the requirement for performance evaluation. The great beauty of the knowledge-based approach is not that knowledge-base is easier to debug than more traditional code (it isn't), but that the knowledge itself is coded only once. It is not embedded in code devoted to a specific purpose and is not divided up between tables and code. Instead, the simulated team member inference engine will make one use of the production rule related to event E, while the performance measurement inference engine will make another use of it. To provide feedback, a third engine, a rule-to-English translator, can be used to translate the rule into English. Other ways of providing feedback are also possible based upon the information in the rule. For example, Goldstein and Grimson (1977) suggest associating a rationale construct with each rule precisely for this purpose.

The knowledge-based approach appears then to offer the possibility of providing a more maintainable, and, in some ways, a more efficient way of doing traditional event-related performance monitoring. There are other potential advantages as well. A crucial element in the design of a knowledge base which is to be used for the simulation of a team member's behavior is the articulation of the rules by which potential actions are given priorities. Some tasks can be performed in parallel while others cannot, and the simulated team member often must pick the best of several good alternative courses of action. If the performance evaluator judges the trainee's action against this list of possibilities with assigned priorities, it is able to make a qualitative assessment of behavior which is not necessarily "wrong." Furthermore, the double bind alluded to in the paragraph devoted to problem areas, wherein two actions defined *a priori* to be required cannot both be accomplished, is completely circumvented: if the trainee selects the better alternative, the system is able to recognize that the situation dictated the omission

of the other. This method then provides the potential for a much finer resolution of the quality of performance than is possible with simple, event driven, pass/fail logics, which collect only errors.

The foregoing discussion has focused upon individual behaviors in the team context. What about the issue of team performance evaluation? Does the approach offer any potential benefit there? One difficulty has been to arrive at a definition of effective team performance. One suggestion has been to define team effectiveness on the basis of the degree of intelligence of the adversary it is capable of overcoming. This is obviously a good measure for use by a fleet commander who must decide how to deploy his forces, but it may not be of much pedagogical value other than to discriminate between those teams which need more practice and those which do not. Harkening back to the communications control focus of this project, it is clear that communication is regarded as an important aspect of team behavior because it is important that each team member have as complete and accurate a picture of the tactical environment as possible. If crucial aspects of this individual internal representation could be inferred from individual performance, and if these model world views of each team member could be compared with one another by the system, it might be possible to have both a measure of team functioning and a basis for inferring where a communication breakdown occurred for purposes of providing helpful feedback. This is just one potential inference technique based on the symbolic representation of knowledge which might be pursued to the benefit of team training.

Requirements. The potential utility of a knowledge-based performance measurement system would seem to justify serious consideration of this state-of-the-art approach. There will be significant problems to be overcome in bringing these ideas into a practical application. It is also the case, however, that employing a more traditional approach would be fraught with difficulty and the result would likely prove to be of limited utility.

The first step in actualizing the potential knowledge-based performance measurement system, suitable to the ASW team environment, will be to use the same knowledge base developed for the team member simulations to implement the checks for error events identified to date. As discussed in the implementation plan section, the first stage of this effort shall focus upon post-run performance evaluation based upon the record of events collected during a problem.

RESEARCHER CONTROL IN PERFORMANCE MEASUREMENT SELECTION. The researcher is required to exercise some control over the performance measurement system. It shall be possible for the researcher to override the default conditions and specify which team member's performance is to be evaluated, and to specify that a set of rules which normally would apply to that team member's behavior should be omitted from consideration.

GRADING. It will be necessary to grade each problem in order to arrive at scores which reflect individual and team performance. The knowledge-based

approach offers the potential for arriving at a qualitative assessment based upon a cumulative comparison of student decisions to the decisions made by the expert model, as described above. This is properly a research issue which must await the development of an expert model team member, and of a definition of a measure of closeness to expert behavior. In the interim, however, a measure of performance is required. This grade shall be computed based upon a weighted combination of errors made.

RECORD KEEPING. Complete performance records shall be maintained for each problem. These records shall include performance data specific to each individual, as well as team performance data. At a minimum, the records shall consist of identifying information, problem descriptive information, raw performance data, and the scores assigned by the training system, as well as textual information concerning the researcher's assessment of the problem. These records shall be accumulated into files in such a way as to facilitate statistical analysis of the performance data.

PERFORMANCE FEEDBACK REQUIREMENTS

Several types of automated performance feedback shall be provided. These include:

- intrinsic feedback from the response of the simulated environment to trainee actions;
- optional on-line feedback regarding gross errors in the form of SAU commander queries and recommendations;
- optional on-line prompting when an error is detected;
- post-run plot of the exercise;
- optional team and individual performance feedback;
- optional display of errors made during a specified portion of the problem; and
- optional performance summary reports for instructor use.

These types of feedback are described in the following paragraphs.

INTRINSIC FEEDBACK. The simulated operational environment will provide a source of intrinsic feedback to the trainee in the sense that his actions will result in realistic changes in that environment. Thus, when his action is well chosen, the desirable consequences will be observed. Likewise, when his action is poorly chosen, he will have to deal with the realistic consequences.

FEEDBACK FROM SAUC. The SAU commander model shall, at the researcher's discretion, provide realistic feedback about gross errors to the team in the form of queries and recommendations. A representative sample of events which should cause this intervention is shown in Table 7, along with the dialogue which the SAUC might reasonably initiate in each case.

PROMPTING ON ERROR DETECTION. A research issue involves determining the efficacy of immediate prompting with the correct action when errors are detected.

TABLE 7. SAMPLE OF ERRORS RESULTING IN SAUC INTERVENTION.

Error	SAUC Intervention
Incorrect classification of submarine	SAUC - "Interrogative classification on your contact [track], over." - Repeats classification, or issues a correction. If it is still incorrect: SAUC - "What are the criteria for your classification, over" - Responds with criteria SAUC - "Your criteria meet only the requirements for [correct classification], over"
ASWOC fails to upgrade classification of contact	SAUC - "Interrogative classification of your contact, over" - Responds with upgraded classification
ASWOC preps a bloodhound	SAUC - "Roger, recommend bassett, over"
ASWOC turns in a direction that will take him out of his sector	SAUC - Will roger the turn and define new sectors

Although it may not be possible to provide real-time performance measurement and remediation of this sort in the initial stage of implementation, the need for this capability must be recognized and the feasibility of providing it must be assessed.

EXERCISE PLOT. As a post-run debriefing aid, the system shall provide a graphics display presentation and optional hard copy. This shall include the tracks of the ASW assets: the SAUC ship, training ship, and helicopter. The display will also show the actual track of the submarine, the positions where the contact was plotted, and the weapon's release and water entry points. Utilizing different colors for the actual versus plotted submarine track, TDA and cone of courses will allow these data to be easily distinguished. This display will serve as a visual aid for use by the instructor in debriefing the team. The hard copy is intended primarily for researcher use.

The display lends itself to further expansion to a faster than real-time replay of the problem, with computer generated annotation. This could serve as an excellent source of feedback for the trainees, especially if the annotation included comments about good decisions and actions.

Table 8 shows the characteristics of the post-run plot and describes the additional annotation that could be provided.

TEAM AND INDIVIDUAL PERFORMANCE FEEDBACK. The researcher shall have the option to cause the system to convey its assessment of team and/or individual performance to each trainee. This will allow research to be conducted into the effectiveness of the type and timing of feedback since, for example, Hall and Rizzo (1975) have provided evidence that team feedback is more effective early in training while individual feedback is more effective later. Ultimately, the system could make the decision about the type(s) of feedback to provide based upon the research results. A concern for providing positive feedback must pervade the design so that the feedback provides some motivating influence and does not merely serve as a punisher.

DISPLAY OF ERRORS. It shall be possible for the researcher or trainee to request a display of the errors which the system detected during the previous problem. The error display shall be either a display of all errors, or a display of errors made between specified times during the exercise. This report shall be provided at each trainee station if requested, and/or on the printer. This type of feedback must be provided sparingly since it tends to be overwhelmingly negative, can be very redundant, and may not distinguish between errors of varying severity.

PERFORMANCE SUMMARY REPORTS. The system shall prepare, at researcher request, performance summary reports based upon information in the student files. Three types of reports shall be prepared: 1) reports concerning all teams trained to date; 2) reports concerning the progress of a specific team; and 3) reports concerning individual performance.

TABLE 8. CHARACTERISTICS OF THE POST-RUN DEBRIEFING PLOT.

Display Events (DE) or Team Actions (TA)	Debriefing Plots: Plotted	Debriefing Plots: Actual	Enhancement Possibilities: Special Symbols	Enhancement Possibilities: Pause	Enhancement Possibilities: Pause on Error	Annotation
Datum (DE)	x	x				
Datum error (DE)	x	x				
Cone of courses (DE)	x	x				
Submarine track (DE)	x	x				
SAU track (DE)		x				
FOC/TDA (DE)	x	x				
Helicopter position (DE)	x	x				
Point at which positive control was taken (TA)			x	x		Positive feedback or suggestions for improvement
Buoys dropped (DE)	x	x				
MAD contacts (DE)	x	x			x	Point out error
MADVEC (TA)			x		x	Show correct vectors, explain
Lost contact position (DE)			x	x		Explain probable cause
Entering TDA (DE)	x	x		x		Positive feedback or error explanation
Sonar contact position (DE)	x	x			x	Explain significant error or accumulated small errors
Reclassification of contact (TA)			x	x		Show time late/early, positive feedback or error explanation, including criteria
Weapon prepped (TA)			x	x		Positive feedback or error explanation
Helicopter ordered to clear (TA)			x	x		Positive feedback or error explanation
Maneuver ship to fire (TA)					x	Suggest better maneuver
Flan red executed (TA)			x		x	Explain correct timing
Weapon fired (TA)			x	x		Positive feedback or suggest improvement
Water entry point (DE)	x	x				
Projected retirement course (DE)		x		x		Positive feedback or better alternative

OTHER POTENTIAL TYPES OF FEEDBACK. The potential benefits to training of the knowledge-based approach do not stop with intelligent, qualitative performance evaluation. A natural outgrowth of the approach is to provide explanations of performance evaluations and to suggest better strategies under the given circumstances. This may be possible if an expert model can be developed which employs symbolic decision making rules akin to those used by a real expert, as opposed to using a purely analytic simulation of decision making such as Rapoport's (1967) adaptive case model. If this model is capable of a certain amount of backtracking and has a rationale construct associated with its production rules, then it could potentially provide very helpful explanations and instruction.

ADAPTIVE PROBLEM SELECTION REQUIREMENTS

The system shall have the capability to choose subsequent training problems based upon its measure of team performance. The researcher shall have the capability to override the system's selection.

The requirement for adaptive problem selection in this research device is to allow the capability to be demonstrated. For the demonstration, the capability will be limited to selecting a more difficult, or less difficult problem. The capability for more specific diagn sis, prescription and remediation is not required for several reasons. First, with the subset of knowledge about ASW which will be incorporated into the system, a good diagnosis may not be possible. Secondly, the development of remedial materials is a research issue outside the scope of the present development effort. Finally, an appropriate vehicle for much remediation is some form of individualized CAI, and that capability is very limited in the system as presently conceived.

Table 9 lists a set of increasingly difficult variations on the basic scenario. These variations are representative of the type of problems which could be selected by the adaptive training module to manipulate problem difficulty, although not all will be implemented. Problems of difficulty equal to the current problem will be generated by simply manipulating the initial headings of the players.

COMPUTER AIDED INSTRUCTION REQUIREMENTS

Computer aided instruction, understood as the interactive presentation of textual materials and visual displays in a programmed learning context, is an extremely valuable training strategy. However, it does not represent a technological risk area and so will not be an object of study in the initial version of the team training system. The CAI approach will be used, however, in the collection of representative samples of voice data and for system familiarization, areas crucial to the success of a speech recognition-based training system, because of its effectiveness in these areas. This will provide a meaningful demonstration of the capability in the team training context without incurring the expense of the development of task specific CAI courseware.

TABLE 9. EXAMPLES OF PROBLEMS OF VARYING DIFFICULTY BASED UPON THE SCENARIO.

Problem	Source of Increased Difficulty
Training ship will be given sonar contact well outside the weapons' release range.	• Training ship must maneuver the SAU into position over a longer distance. • ASWOC must make more decisions, communicate more with the assist ship, and communicate more with the ASAC.
Training ship will be given two ASW aircraft to control.	• ASWOC must make decisions regarding aircraft tactics. • ASAC must control two aircraft through these tactics.
Training ship will be given a second sonar contact.	• ASWOC must evaluate the threat to the main body and attack the higher threat.
For any of the above problems, require the ASWFCO to take control for the attack.	• ASWOC must shift control at the proper time. • ASWFCO must maneuver the ship into firing position.
Training ship will not be given sonar contact until the submarine is within range where an urgent attack is required.	• ASWOC must make a snap decision to conduct an urgent attack and maneuver the SAU for a close-in attack. • ASWFCO must prepare and fire an urgent attack. • ASWFCO must override the system to fire the weapon.
In any of the above problems, cause the submarine to change course after sonar contact.	• ASWOC must adjust to counter the threat. • ASWFCO must recompute the fire control problem.
In any of the above problems, cause the submarine to fire a weapon after the training ship initiates the attack.	• ASWOC must maneuver to avoid the the weapon, then to regain the firing position. • ASWFCO must recompute the firing solution.
In any of the above problems, make the threat a nuclear submarine.	• Decreases amount of playing time, all actions must be performed more quickly.

SECTION VII

IMPLEMENTATION PLAN

This report provides a functional description of a system which necessarily employs new hardware technologies and for which a very new kind of software design is being recommended. The result is the definition of a system built largely on unknowns, intended ultimately to solve the problem of automating team training. To assure success, the design and implementation must proceed in carefully considered stages in which only a few unknowns are explored at a time. The following paragraphs describe a three-stage approach to the development and the rationale behind the focus of each stage.

STAGE 1

The proposed Stage 1 implementation would produce a system in which all three simulated team members tackle the ASW problem against a submarine which is under the control of the researcher. The simulated team members will speak and perform all other actions that will be expected of a trainee. The performance monitoring capability will grade their performance after the problem. The Stage 1 system will employ a minimum hardware configuration for purposes of exploring the fundamental adequacy of the knowledge-based approach to team member simulation, some performance monitoring issues, and speech generation techniques. The rationale for starting with these research issues is described in the paragraphs which follow.

KNOWLEDGE-BASED APPROACH. It has been argued in this report that the time has come to attempt to vastly improve automated training by employing a knowledge-based approach. The successful codification of team member knowledge is important for several reasons: the team member simulation which uses this knowledge will allow team training to occur even when a team member is missing, a common problem in military team training; the knowledge itself will provide the basis for evaluating team member behavior; it will be the source of prompts; and it will provide hypotheses about expected speech communications which may prove crucial for guiding speech understanding.

The risk in the approach is a practical one. It must be determined whether or not it is possible to implement the approach in a real-time environment. While there is evidence that it is possible, it is not a routine implementation task and constitutes a risk area.

PERFORMANCE MONITORING. Performance monitoring, evaluation, and feedback in the team training environment represent virtual unknowns. What is well understood is that these aspects of training are crucial to the success of a training system. Furthermore, experience has shown that the checking for consistency among performance measures, the checkout of the implementation, and the refinement of the measures as experience is gained on the system are tasks often necessarily relegated to the final stages of the development,

with the undesirable consequence that one of the most crucial training aspects of the system is not as thoroughly tested as it should be at the time the first trainee begins to use the system.

With the knowledge-based approach to performance monitoring, there is a potential for early and thorough investigation of the performance measures. Stage 1 attempts to capitalize on this potential in order to give the automated performance monitoring function the visibility it deserves and the development time it needs. A further important aspect of the choice is that exercising the performance monitoring function on simulated team member performance will augment the debugging of the model team member. Finally it will enable the performance monitor to be debugged before the confounding influence of potential speech misrecognition is introduced.

This approach has some interesting design implications. In particular, the simulations and the performance monitor are required to have meta knowledge, that is, they will need to know what they know. In this way, for test purposes, the simulation can be given incorrect knowledge which is not represented in the performance monitor's knowledge. A software architecture which uses a meta-knowledge superstructure is consistent also with a parsimonious approach to knowledge base construction, since a great deal of each team member's knowledge overlaps that of other team members.

SPEECH GENERATION. There are a number of problems in the speech generation area which must be tackled. First, team members get verbal communications from a large number of people, each of whom must have a unique voice. Secondly, these simulated persons talk over different circuits. Finally, these communications must be retrieved and perhaps constructed to provide timely responses to the team members. The rationale for approaching this problem in the first stage is that being able to hear the interactions will greatly facilitate the debugging and refinement of the team member models.

SAMPLE STAGE 1 WORK PLAN. Table 10 shows an outline of the work which will need to be performed during Stage 1, and Figure 12 shows a very preliminary time line for this effort. Tasks 1 and 2 are primarily intended to validate, refine, and extend the specifications in the functional definition as necessary to support the design effort. Part of task 1 and task 3, the specification of speech understanding requirements and the implied speech recognition hardware modifications, are shown as Stage 1 tasks for the reason that our experience with procuring similar modifications leads us to recommend early specification and dialogue with the manufacturer to ensure the availability of a device with the requisite capabilities in time for the Stage 2 work which requires it.

Task 4 involves the detailed design of Stage 1 software components. This work can proceed to some extent during the hardware procurement cycle.

TABLE 10. OUTLINE OF STAGE 1 TASKS.

Task	Description
1	Verify and enlarge upon the specification of the functional requirements for: * the detailed knowledge about the problem > team member knowledge and behavior > environment specification * the performance measurement system * the adaptive logic * the speech generation system * the researcher/instructor interface * the speech understanding system
2	Validate proposed hardware, software languages, and operating system selections for the Stage 1 system and initiate procurement
3	Specify necessary modifications to existing speech recognition hardware, initiate dialogue with manufacturer(s)
4	Design software: * the knowledge base * the executive * the team member models * the supporting simulations * the performance measurement system * the adaptive logic * the speech generation system * the researcher/instructor interface * the support modules (graphics capability, researcher/submarine interface, etc.)
5	Design any special purpose hardware
6	Implement hardware designs, configure hardware system
7	Implement stand alone checkout of software
8	Integrate software, system level checkout
9	Fine tune system
10	Evaluate the feasibility of the approach and the implications of lessons learned for subsequent stages of the development

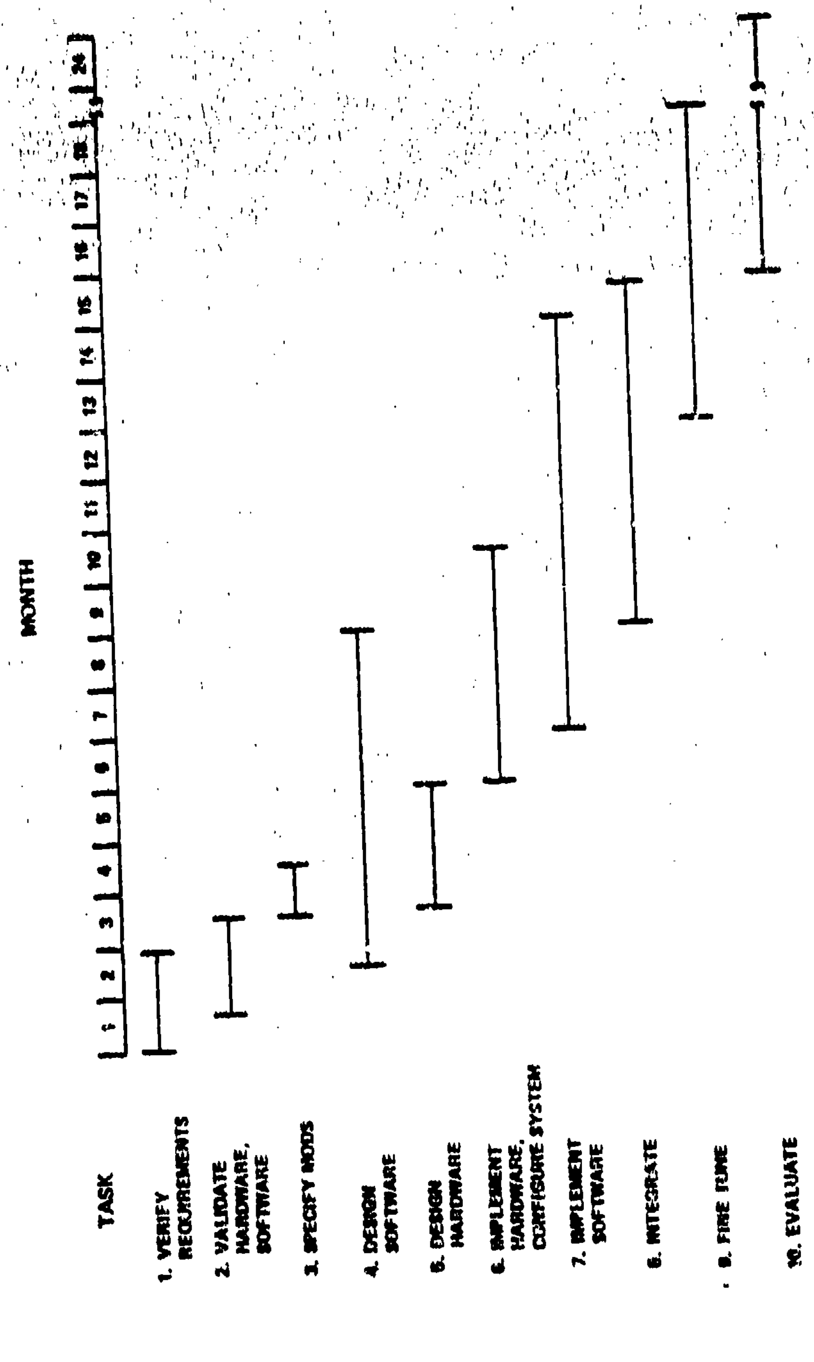


Figure 12. Preliminary time line for Stage 1 tasks.

Tasks 5 and 6 involve the fabrication of any special purpose devices and interfaces that may be required, as well as configuring the hardware equipment suite.

Tasks 7 and 8 relate to the software implementation effort and the integration of software system components.

Task 9 is shown in recognition of the fact that model behavior and performance measurement system operation are best refined in the context of a working system. The researcher needs ample time to hone these all important training system elements before the system is subjected to a real trainee.

Finally, task 10 provides the opportunity to specify guidelines for the next stage of the implementation in the light of the lessons learned to date.

STAGE 2

When the Stage 1 system reaches the state of refinement in which the adequacy of the methods and hardware has been demonstrated, it will be necessary to generate a detailed Stage 2 plan in the light of the lessons learned in Stage 1. The focus of the Stage 2 can be sketched here, however. The intent is to add the capability to support the training of one team member. This will entail the addition of hardware and software to the Stage 1 system. The hardware will include a speech recognition device, probably one especially configured based upon the recommendations developed in Stage 1; a color graphics capability; and additional computer support. The software will include the speech understanding software which interprets the potentially noisy speech recognition device output; the interface between speech understanding and the rest of the system; speech data collection; the full computer generated submarine model; additional graphics support; and perhaps real-time performance measurement.

The Stage 2 system will be used to investigate solutions to the understanding of connected speech in the ASW CIC environment and to answer questions about the effective use of feedback and the use of performance data in adaptive problem selection. It will also provide particularly valuable information about the effectiveness of the simulated team members in functioning with a human team member.

Stage 2 is regarded as a crucial interim stage for several reasons. First, even though a body of knowledge has been accumulated about understanding the speech of one person talking to a computer, the ASW vocabulary is extensive, and some provision must be made, if possible, for understanding language which is not necessarily perfectly structured according to rules imposed for the sake of computer recognition.

Secondly, the efficacy of the speech recognition hardware modifications should be evaluated before further device procurement is initiated

Thirdly, although Stage 1 will insure that the simulated team members can function as a team, there will undoubtedly be much to learn when a human functions as one of the team members.

Finally, the Stage 2 device will provide the researcher with a tool for studying the effective uses of performance data for feedback and adaptive problem selection.

STAGE 3

Stage 3 will involve extending the system capacity to accommodate all three team members. This extension will be based upon all the lessons learned in Stages 1 and 2, and especially upon the results of the speech understanding work. The new speech understanding problems which will arise in this stage are those associated with understanding the communications between human team members, since the team may tend to revert to less structured, less intelligible speech between themselves than is used in communicating directly with the simulations. It is necessary for the system to understand this communication as best it can in order to be able to detect communications breakdowns. This will likely call for increasing sophistication and refinement of the speech understanding logic, and support from the team member models.

It is in this stage also that research into issues regarding team behavior can be conducted, especially into motivating such behavior and the effective user of team versus individual feedback.

SECTION VIII

CONCLUSIONS AND RECOMMENDATIONS

This document has presented a preliminary system design for a team training demonstration system based on extensive analysis of the team training problem in an ASW environment. It is believed that the system which is described here would provide a valuable tool for further detailed investigation of team training, and would contribute significantly to the development of actual automated team training devices. It is recommended that the staged implementation plan described in this report be carried out.

There are, however, three areas in which short-term action is recommended to enhance the speedy development of team training technology and to improve existing training. These will be discussed in the following paragraphs. The reader is urged to review the chapter which presents the staged implementation plan inasmuch as two of the items which follow simply highlight features of that general plan.

SPEECH TECHNOLOGY

The amount of communications which take place in a Combat Information Center is simply staggering. When the sheer bulk of these communications is considered, and the crucial dependence of mission success on communication is noted, it becomes clear that speech technology has vital importance in the development of an automated training device for this environment and many like it. Automated performance measurement--sorely needed by overburdened instructors--is not practical without a reasonably reliable automated speech understanding capability. It has been noted that understanding of team training issues has long been hampered for lack of detailed, objective performance measurement, and manual methods of accomplishing performance measurement are neither practical nor adequate. In the last few years, automated systems for training individual students have been built which successfully integrate adaptive training, automated performance measurement, and automated speech recognition and speech generation (Grady, in press; Hicklin et al., 1980).

It now appears that the time has arrived when these emerging technologies can be applied to team training. But speech technology, particularly speech recognition, is the crucial element in this scheme, and it is still developing. It is strongly recommended that the state of speech technology be regularly monitored and that new techniques and new devices be evaluated quickly as they appear.

KNOWLEDGE-BASED SIMULATION

A significant consequence of this study and design effort has been the recognition that a knowledge-based approach toward simulating team members is very desirable given the complexity of the team training situation and the complication of the ASW world. The advantages of having a knowledge-based

model of each team member include not only the capability of providing a high fidelity simulation of missing team members, but also the facility for comparing expert model performance to that of the trainee. The knowledge-based modeling approach thus strengthens the capabilities of performance measurement and allows for more intelligent feedback to the trainee. Furthermore, if the knowledge base includes rules about performance measurement and training techniques, the knowledge-based system approach becomes an attractive means for automated performance measurement and adaptive logic. It is strongly recommended that the technology of knowledge-based modeling of expert behavior be vigorously pursued.

COMMUNICATIONS

The current study has recommended a training approach designed to promote strong team formation. This approach includes training to (1) emphasize the critical communications required of each team member, including both those communications properly theirs as well as communications made to backup fellow team members, (2) instill a shared sense of identity, and (3) develop a shared set of goals. Weaknesses in ASW teams which have been observed during training include inadequate flow of information between team members, misunderstanding of mutual relationships, and vagueness about team goals. While current training formally recognizes the importance of team communications (see Appendix L), there is little or no explicit emphasis on communications. It is recommended that (1) instructors be made aware of the need for training a team to communicate, as well as being informed of methods to develop good team communications skills, and (2) instructional materials dealing with communication issues be developed for early use in the team training syllabi. Because team communication problems are so crucial, there is a pressing need for even partial solutions as soon as possible.

REFERENCES

Bell, J. D. Final Technical Report, Performance measurement in anti-submarine warfare (ASW) team training. (TD 085-78) West Covina: Honeywell Defense Electronics Division, September 1978.

Boguslaw, R. and Porter, E. H. Team functions and training. In: Psychological principles in system development. Gagne, R. M. (Ed) New York: Holt, Rinehart and Winston, 1962.

Briggs, G. E. and Johnston, W. A. Laboratory research on team training. Port Washington: Naval Training Device Center, NAVTRADEVCEN 1327-3, May 1966.

Chapanis, A. Prelude to 2001: Explorations in human communication. American Psychologist, 1971, 26, 949-961.

Chapanis, A. Interactive human communication: Some lessons learned from laboratory experiments. Paper presented at NATO Advanced Study Institute on Man-Computer Interaction, Mati, Greece, September 1976.

Chapanis, A., Parrish, R. N., Ochsman, R. B., and Weeks, G. D. Studies in interactive communication: II. The effects of four communication modes on the linguistic performance of teams during cooperative problem solving. Human Factors, 1977, 19, 101-126.

Collins, J. J. A study of potential contributions of small group behavior research to team training technology development. Final Technical Report, ONR Contract No. 00014-76-C-1076, Nr 170-834, Alexandria: Essex Corporation, 31 August 1977.

Davis, R. and King, J. An overview of production systems. In Elcock, E. W. and Michie, D. (Eds), Machine intelligence, Vol. 8, Halstead Press, 1977.

Dertouzous, M. L. and Moses, J. (Eds) The computer age: A twenty year view. Cambridge: MIT Press, 1979, pp 56-72.

Erman, L. D., and Lesser, V. R. The HEARSAY-II speech understanding system: A tutorial. In Lea, W. A. (Ed), Trends in speech recognition, Prentice-Hall, 1980.

Glaser, R., Klaus, D. J. and Egerman, K. Increasing team proficiency through training: 2. The acquisition and extinction of a team response. Technical Report AIR B64-5/62, American Institutes for Research, May 1962.

Goldstein, I. P. and Grimson, E. Annotated production systems: A model for skill acquisition. Massachusetts Institute of Technology, Technical Report MIT-AI 407, 1977.

Grady, M. W. Air intercept controller prototype training system, final technical report. Contract No. NAVTRAEQUIPCEN 78-C-0182-14, Orlando: Naval Training Equipment Center, in press.

Hall, E. R. and Rizzo, W. A. An assessment of U.S. Navy tactical team training: Focus on the trained man. TAEG Report No. 18, Training Analysis and Evaluation Group, March 1975.

Hicklin, M., Barber, G., Bollenbacher, J., Grady, M., Harry, D., Meyn, C., Slemon, G. Ground controlled approach controller training system final technical report. Contract No. N61339-77-C-0162, Orlando: Naval Training Equipment Center, 23 April 1980.

Horrocks, J. E., Krug, R. E. and Heerman, E. Team training II: Individual learning and team performance. Port Washington: Naval Training Device Center, NAVTRADEVCEN 198-2, August 1960.

Jeantheau, G. G. The use of multi-man system trainers. Ergonomics, 1969, 12 (4), 533-542.

Johnston, W. A. and Briggs, G. E. Team performance as a function of team arrangement and workload. Journal of Applied Psychology, 1968, 52 (2), 89-94.

Kanarick, A. F., Alden, D. G. and Daniels, R. W. Decision making and team training in complex tactical training systems of the future. In 25th Anniversary Commemorative Technical Journal. Port Washington: Naval Training Device Center, 1971.

Klaus, D. J. and Glaser, R. Increasing team proficiency through training: 8. Final Summary Report. ONR Contract Nonr 2551(00) (Nr 154-079), Team Training Laboratory, American Institutes for Research, 1968.

Kurke, M. I. Operational Sequence Diagrams in system design. Human Factors, 1961, 3(1), 66-73.

Lanzetta, J. T. and Roby, T. B. The relationship between certain group process variables and group problem-solving efficiency. The Journal of Social Psychology, 1960, 52, 135-148.

McCauley, M. E., and Semple, C. A. Precision approach radar training system (PARTS) training effectiveness evaluation. Contract No. N61339-79-C-0042, Orlando: Naval Training Equipment Center, August 1980.

McDermott, J. R1: The formative years. AI Magazine, 1981, 2 (2), 21-29.

Meister, D. Behavioral foundations of system development. New York: John Wiley, 1976.

Nieva, V. F., Fleishman, E. A. and Rieck, A. Team Dimensions: Their identity, their measurement and their relationships. Final Technical Report, Contract No. DAH19-78-C-0001, Washington, D. C.: Advanced Research Resources Organization, 20 November 1978.

O'Brien, G. E. and Owens, A. G. Effects of organizational structure on correlations between members abilities and group productivity. In: Bass, B. M. and Deep, S. D. (Eds) Studies in organizational psychology. Boston: Allyn and Bacon, 1972.

Popelka, B. A. and Knerr, C. M. Team training applications of voice processing technology. Final Report, DARPA Contract No. MDA903-79-C-0209. Springfield: Mellonics Systems Development, 31 March 1980.

Post, E. Formal reductions of the general combinatorial problem. American Journal of Mathematics, 1943, 65, 197-268.

Rapoport, A. Dynamic programming models for multistage decision making tasks. Journal of Mathematical Psychology, 1967, 4, 48-71.

Rizzo, W. A. Navy team training: Some critical issues. In Golden, S. E. and Thorndike, P. W. Proceedings of the RAND team performance workshop. ONR Contract N00014-79-C-0753, Working Draft 547-ONR. Santa Monica: RAND Corp., March 1980.

Smith, D. H. A parsimonious definition of "group": Toward a conceptual clarity and scientific utility. Sociological Inquiry, 1967, 37(2), 141-167.

Smode, A. F. Training device design: Human factors requirements in the technical approach. Orlando: Naval Training Equipment Center, NAVTRAEQUIPCEN 71-C-0013-1, August 1972.

Steiner, I. D. and Dodge, J. S. Interpersonal perception and role structure as determinants of group and individual efficiency. Human Relations, 1956, 9, 467-480.

Tribault, J., Strickland, L. H., Mundy, D. and Goding, E. F. Communication, task demands, and group effectiveness. Journal of Personality, 1960, 28, 156-166.

Wagner, H., Hibbits, N., Rosenblatt, R. D. and Schulz, R. Team training and evaluation strategies: State-of-the-art. HUMRRO Technical Report 77-1, DARPA Contract No. MDA903-76-C-0210. Alexandria: Human Resources Research Organization, February 1977.

Williges, R. C., Johnston, W. A. and Briggs, G. E. Role of verbal communication in teamwork. Journal of Applied Psychology, 1966, 50(6), 473-478.

Winograd, T. Toward convivial computing. In: Dertouzous, M. L. and Moses, J. (Eds) The computer age: A twenty year view. Cambridge: MIT Press, 1979.

Zander, A. Motives and goals in groups. New York: Academic Press, 1971.

APPENDIX A

TRAINING TECHNOLOGY BACKGROUND

The Naval Training Equipment Center (NAVTRAEQUIPCEN) has established the efficacy of various training automation technologies, notably adaptive training, automated performance measurement, and computer-based speech recognition and voice generation. The combined applications of these technologies have reduced the instructor-trainee ratio, reduced training time, and increased training standardization, while maintaining high quality and efficiency. These observations have been derived from flight training systems and ground controller training systems (Hicklin et al., 1980; McCauley and Semple, 1980; Grady, in press). This project, Team Training Through Communication Control, seeks to extend the benefit of these technologies to the team training environment.

WHERE DOES THIS PROJECT FIT INTO TECHNOLOGY DEVELOPMENT?

A complete Team Training Automated Training System will encompass the following major subsystems:

- Simulation - the environment for practice
- Replay - for self-review and self-critique
- Performance Measurement - the basis for student assessment
- Feedback - for automated evaluation and self-critique
- Adaptive Logic - for automated self-pacing
- Computer Aided Instruction - for teaching the material
- Diagnosis and Remediation - for "instructorless" training.

A review of the history of some familiar Navy training programs charts the development of these various subsystems.

TACDEW - simulation, replay, very simple performance measurement
AFTS - simulation, replay, performance measurement, simple feedback, simple adaptive logic
GCA-CTS - simulation, replay, performance measurement, feedback, adaptive logic, simple computer aided instruction, simple diagnosis and remediation
ACE - all of the above, none of it simple!

As we embark on the team training program, we pose the question of what, if anything, makes this application of automated training system design concepts so different? Is this project concerned with the continued development of the subsystems named above? What makes this project truly developmental in nature, and not just a re-application of the technologies used in those earlier programs?

A considerable level of research is being conducted in team training issues. See, for example, the proceedings of the Team Performance Workshop held at RAND in August, 1980. This wide ranging research is a very important

element whose impact on the specification of an eventual operational trainer will be significant. NAVTRAEQUIPCEN's participation in this research is characterized by focusing on team communications and training automation as important aspects of team performance and team training; and insisting, from the start, that the results of the R&D have "credibility and utility in the eyes of the operational Navy, as well as methodological precision" (Rizzo, 1980). Note that this statement does not necessarily imply that the R&D tools will replace or even augment any existing training program or device. It does, however, demand that the R&D be structured around real Navy problems and certainly not be counter-productive or even non-productive for potential operational Naval subjects. It demands a system that trains, but not necessarily a Training System.

PURPOSE

The focus upon team communications and training automation provides the guideline for scoping the problem in terms of R&D objectives, goals, and issues. From this baseline of clear and concise objectives, the need to offer credibility and utility in the eyes of the operational Navy provides the framework for defining the operational and functional aspects of a Research/Demonstration System. This name captures the notion that it is a demonstration to the operational Navy of certain instructional strategies and automation technologies as applied to a training problem with which they can relate; and it is a demonstration to the R&D community of these same strategies and technologies applied in a experimental tool for their use and study. It also underscores the distinction between the multi-faceted goals of this experimental system with the more pragmatic compromises that are required in any operational trainer. Most importantly, the name conveys the important role of this system as a research tool for examining the crucial questions which must be answered before designing an operational training system.

R&D OBJECTIVES. The basic R&D question posed by this program is: Can team performance be improved through automated training in team communications?

More specifically:
What is the nature of team communications?
How can team communications be taught?
How can it be practiced, measured, and evaluated?
How can communication problems be diagnosed and weaknesses remediated?

Reflecting upon these questions naturally leads to other questions, answers to which must be provided before an efficient and effective training device can be specified.

Do communication skills correlate well with team performance? If so, can team communication be measured, evaluated, and interpreted to predict team performance? How does this differ from

predictions based on observation of trainee's communications skills when practiced individually? Can a standard be defined? Can we determine the communications skills of a "good" team?

Can communications be controlled sufficiently to adapt the training situation to the unique strengths and weaknesses of the individual team members and the team as a whole? Is communications a good adaptive variable? What aspect would one want to adapt: informational content, frequency, style, etc.? How do we model this range of communications skills?

Can a simulation environment which stresses the communication channels be created with sufficient fidelity to provide valid answers to research issues addressed within that environment? Can we simulate verbal communications of the various team members sufficiently realistically to provide face-validity to the trainee? Can the supporting technologies provide _what_ to say (as well as _how_ to say it) in a dynamically changing environment?

What are appropriate instructional strategies and media to be used in teaching team communications? What is the role of CAI, video disc-based instruction, the simulator, live practice, etc.?

What are the most appropriate feedback techniques? What should be the feedback content? Should feedback be directed to the entire team or just the individual to whom it applies? When must the feedback be given: immediately or after a mission?

In terms of R&D objectives, then, the purpose of this program is to provide an experimental tool which is sufficiently robust and flexible to support research to answer these and similar questions.

SYSTEM DESIGN OBJECTIVES. In terms of system design considerations, there are in fact a number of fundamental differences in this program. One difference includes but extends beyond the fact that a _team_ is the "trainee" and that _communications_ is the focal issue. A particularly important and basic difference which will significantly effect the design of the subsystems named above, is that we are attempting to apply automated and adaptive techniques to a primarily _emergent_ situation as distinguished from a primarily _established_ situation. Because of its significance, we will examine this aspect of the program throughout various sections of this report. Briefly though, these terms are explained as follows:

An established situation is one in which (1) all action-relevant environmental conditions are specifiable and predictable, (2) all action-relevant states of the system are specifiable and predictable, and (3) available research technology or records are adequate to provide statements about the probable consequences of alternative actions. An emergent situation is one in which (1) all action-relevant

environmental conditions have not been specified, (2) the state of the system does not correspond to relied-upon predictions, and (3) analytic solutions are not available, given the current state of analytic technology (Boguslaw and Porter, 1962).

It is important to note here that the authors underscore that any given context is actually a continuum of situations, the end points of which are described as established or emergent.

AFTL and GCA-CTS were clearly applications biased toward established situations. Flight procedures, flying final PAR approaches, conducting GCA control, are all tasks which are well defined, specifiable, and predictable. The introduction of randomness into these systems, through simulated emergencies or non-deterministic pilot and wind models, in fact did provide some unpredictability from the trainee's perspective, but certainly not the system's. The response by the learner was equally well specified to the system's simulation and performance measurement subsystems given these modifications from the norm. To the extent that the training task and environment become less well defined, for example in some AIC tasks, the training system designer has resorted to a rigidly specified scenario which in fact once again constrains the situation to cause and effect relationships. In summary, many, if not all, applications of automated and adaptive training technologies and instructional strategies have been applied to situations which are more established than emergent.

Now if one were solely interested in developing "just another" ASW Trainer, albeit with some automated and adaptive features, one might be tempted to adopt an approach which similarly constrained the ASW team tasks via carefully defined scenarios and relatively "hard coded" (deterministic) subsystems. Even if this approach proved viable (which we doubt), the desire to examine generic team tasks and to extend the results of the R&D effort to other team environments, suggests that "just another" trainer designed along the more traditional guidelines is not an appropriate objective of this program.

Much of the basic research conducted in team training confirms one's intuition that team training devices and techniques require an orientation toward emergent, unstructured situations. For example, Wagner (1977) reports that:

> An emergent situation permits a more realistic, less abstract approach to the investigation of team training variables than does an established situation. When a team was formed in the laboratory, its prior motivational characteristics were important determinants of performance. But, when teams were studied while carrying out face-valid activities, prior motivational states appeared to be less important. What was important in this case was training in

coordination such that team members became fully aware of their responsibilities to compensate for the inabilities of others, or to overcome temporary problems when the situation called for it.[1]

SUMMARY. To return to our earlier questions then, this project provides both the opportunity and the requirement to extend automated and adaptive training into situations, like ASW, which involve team activities in primarily emergent situations. We are challenged to push the state of analytic technology to provide solutions which heretofore have not been available. To summarize then, this project must develop, test, and demonstrate automated training technologies

- as applied to <u>team</u> performance
- focusing on <u>communications</u> control
- in a <u>dynamic</u> (ASW) environment.

ASSUMPTIONS AND CONSTRAINTS

What does this imply about the system configuration? We currently envision a demonstration system emphasizing simulation and performance measurement. The Simulation Subsystem will include relatively traditional modules for platform motion models (aircraft, surface ships, and submarines), detection models (active and passive sonar, and magnetic anomaly detection), and support personnel (sonar operators, fire control specialists, bridge personnel, pilots, etc.). The major emphasis, however, will be placed on developing new techniques to model the principal team members: the ASAC, ASWOC, and ASWFCO. It is here that the real challenge of accurately and realistically replacing or augmenting the (human) team member in a dynamically changing environment will be met. Some form of knowledge-based simulation is perhaps the path to success in this area. Simulating realistic communications will be a particularly important area, not so much in terms of how to generate the speech, as in formatting appropriate, human-like messages. Speech recognition will be required when the state-of-the-world cannot be deduced from other user inputs such as NTDS button pushing. (The major contribution of speech recognition is in supporting performance measurement, discussed later). The trainee stations are currently conceived to be based upon a graphics terminal augmented with a track-ball or joystick, touch entry pad, and functional keyboard. No attempt will be made to develop "look-alike" consoles which emulate the operational equipment. Nevertheless, the stations will have sufficient fidelity so that operational Navy observers or users will not require a quantum leap of imagination to see the appropriateness of the system.

---

1. Note that this statement does not imply that team member A must be able to perform the job, explicitly, of team member B; but rather that member A must be able to compensate for inadequacies of member B's performance. Wagner cites George, C.E., <u>The view from the underside: Task Demands and Group Structures</u>, Professional Paper 11-6V, Alexandria, Virginia: Human Resources Research Office, 1967

APPENDIX B

TEAM TRAINING RESEARCH BACKGROUND

A review of the team training literature was conducted. Fortunately, there were excellent recent reviews already in existence (e.g., Collins, 1977; Nieva et al., 1978; Popelka and Kerr, 1980; Rizzo, 1980; and Wagner et al., 1977). The objective of this review was to establish a research focus for the development of a research device specifically containing the emerging technologies of adaptive training, automated performance measurement, and computer voice recognition and synthesis.

This review generally reinforced the notion that team training research is indeed in an early stage. Consequently, it was believed appropriate for this review to emphasize research which is both fundamental and clearly essential for the development of improved team training methods. For example, fidelity of simulation issues were believed to be secondary to an understanding of team phenomena and effective training methods; furthermore, such fidelity considerations probably would increase the research system complexity and cost. Some research issues highlighted in the literature were ignored because these would require sweeping changes in Navy procedures; for example, the structure of Navy teams was taken as a given, since change would be required throughout the training system, the rating system, and equipment design.

As a result of this selection process, the following topics were derived from the literature review as relevant to the current effort: definition of "team," communications, feedback, training sequence, environment, and performance measurement.

DEFINITION OF TEAM

Before team training research can be sensibly structured, one needs to define the term "team." On the other hand, there is a dilemma as the definition also represents a theoretical construct requiring research for enrichment. Furthermore, since most related research has been performed on "small groups," there is a need to also consider the definition of "group." Collins (1977) has performed an excellent piece of work comparing the literature in these two research areas.

Rather than list the multitude of definitions for team and small group, only a selected few will be presented, as the commonality is greater than the differences. Rizzo (1979), for example, chooses the definitions of Klaus and Glaser (1968):

> ...a team is usually well organized, highly structured, and has relatively formal operating procedures--as exemplified by a baseball team, an aircraft crew, or ship control team. Teams generally:

- are relatively rigid in structure, organization, and communication networks,
- have well defined positions or member assignments so that the participation in a given task by each individual can be anticipated to a given extent,
- depend on the cooperation or coordinated participation of several specialized individuals whose activities contain little overlap and who must each perform their task at least with some minimum level of proficiency,
- are often involved with equipment or tasks requiring perceptual-motor activities,
- can be given specific guidance on job performance based on a task analysis for the team's equipment, mission, or situation.

A small group, on the other hand, rarely is so formal or has well-defined, specialized tasks--as exemplified by a jury, a board of trustees, or a personnel evaluation board. As contrasted with a team, small groups generally:

- have an indefinite or loose structure, organization, and communication network,
- have assumed, rather than designated, positions or assignments so that each individual's contribution to the accomplishment of the task is largely dependent on his own personal characteristics,
- depend mainly on the quality of independent, individual contributions and can frequently function well, even when all or several members are not contributing at all,
- are often involved with complex decision-making activities,
- cannot be given much specific guidance beforehand, since the quality and quantity of participation by individual members is not known.

Wagner et al. (1977) adds "teams are goal, or mission-oriented and so the specific context in which the team will operate must be considered before any training or evaluation technique can be applied."

Collins (1977) frames his discussion in terms of the definition by Smith (1967), which includes:

(1) the largest of two sets of two or more individuals jointly characterized by

(2) a network of relevant communications,

(3) a shared sense of collective identity, and

(4) one or more shared goal dispositions with associated normative strength.

Collins notes that the above definition of group is considered to be of maximum use because its elements represent a "critical mass" in a real empirical sense. There should be a sharp increase in the probability that grouplike phenomena will occur once observable configurations of events satisfy the four definitional requirements. According to Zander (1971), these useful properties include:

1. awareness of accomplishment
2. feelings of satisfaction
3. stronger desire for success
4. groups work harder
5. coordinate their efforts more effectively
6. less strain on interpersonal relations
7. more attracted to membership
8. group becomes more productive

It would appear that a first stage in team training should address the four requirements of a group, to ensure establishment of a strong group, which, in turn, should lead to the multiple benefits of grouplike phenomena.

COMMUNICATIONS

Upon examination of ASW teams in operation, it is clear that interaction between team members takes two direct forms: (1) verbal communications and (2) information passed through console actions resulting in display changes. (A third, indirect form, is the effect of task performance by one team member on the task of another member.) Communications, therefore, embody the team interactions, and are obviously critically important to team performance.

Collins (1977) reports that several work conditions (such as efficient routing of necessary information or direct and rapid access to information) have a positive effect on group performance. However, Popelka and Knerr

(1980) note that "Steiner (1966) applied the term "process loss" to the degradations of team productivity produced by individual processes and he empirically demonstrated process loss effects" (Steiner, 1972) and that "communications are an example of team processes that diminish team performance." Even more strongly, they say that "the most consistently demonstrated effect of communication on team performance is that the extent of communication is inversely related to team productivity" (Johnston and Briggs, 1968; Meister, 1976; O'Brien and Owens, 1972: Steiner, 1972).

However, Nieva et al. (1978) point out the results are mixed, depending on the task situation:

1. While communication appears to have positive effects on problem solving tasks, the opposite was generally found among vigilance-monitoring studies.

2. Steiner and Dodge (1956) found that communication improved performance in unstructured tasks but communication had no effect on structured tasks. Also, Thibault, et al. (1960) found that intragroup communication is especially critical with unstable task demand; the concept of stability is closely related to structure.

3. Lanzetta and Roby (1960) found that the number of requests for information was negatively related to performance while the ratio of volunteered to total information was positively related to performance.

Clearly, communications is a fundamental team research area. It would appear that the passing of essential information between team members is a basic requirement, and that team performance will be diminished if these items of information are not passed. However, the efficacy of additional information is a moot research question.

FEEDBACK

"Performance feedback is unquestionably the single critical parameter in team or individual training" (Kanarick et al. 1971). Klaus and Glaser (1968) conclude "...it appears essential that team practice result in clear and immediate reinforcement following each correct team response; practice in the absence of team reinforcement for criterion-level performance is more likely to lead to a decrement in team proficiency." Such is the status of feedback about trainee performance or knowledge of results (KOR). There seems to be general agreement on this point; however, beyond this not much else is clear with regard to design for optimal feedback.

Hall and Rizzo (1975) list some of the problems identified by Alexander and Cooperland (1965):

1. There may be several criteria of effective team performance with no clearcut tradeoffs among them. These criteria may be vague and difficult to state objectively and may change during system operations.

2. In order for a team to operate effectively, it is necessary for its members to develop and maintain individual skills as well as skill in working together. There is a possibility that these skills may require different feedback procedures which may mutually interfere.

3. When a complex system operates, there is usually a large volume of information available about the state of the environment, the state of the system, and the performance of system personnel. Some of this information may be conducive and some inimical to effective learning.

To date, the research on feedback or KOR has served to show the complex issues involved in designing optimal feedback for team training. The findings of Briggs and Johnston (1966), as briefly summarized below, serve to make this point.

1. Use of individual-specific KOR is desirable when one team member cannot compensate for the other.

2. Low-ability personnel may benefit from either individual or team KOR, but high-ability personnel may benefit from individual KOR, and performance may deteriorate under team-specific KOR.

3. Members will attempt to maximize performance about which they receive specific KOR; furthermore, this improvement may be at the expense of other characteristics of team performance.

4. If highly specific KOR is given early in team training, it would actually interfere with skill acquisition.

Hall and Rizzo (1975) conclude:

> Unfortunately, many relevant questions which would logically arise in attempting to apply KOR to a team training situation are, at best, only partially answered by the laboratory research in this area.
>
> A partial list of such questions follows:
>
> 1. When should information be provided?
>
> 2. What information should be provided?

3. Who should receive feedback?

4. How should KOR be provided?

5. Who should provide KOR?

6. How much of what kind of KOR should be provided at various learning stages?

Clearly, feedback is an area requiring emphasis in team training research.

EMERGENT/ESTABLISHED ENVIRONMENTS

The literature treats team tasks differently depending on the environment: a "stimulus-response" model is applied where the tasks can be almost completely specified and team assignments are fixed; and an "organismic" model, where the team is treated as an organism of which the individuals are components, is applied when the individuals have considerable discretion in the manner tasks are performed for different contingencies. These two task environments have been defined by Boguslaw and Porter (1962) as follows:

> An established situation is one in which (1) all action-relevant environment conditions are specifiable and predictable, (2) all action-relevant states of the system are specifiable and predictable, and (3) available research technology or records are adequate to provide statements about the probable consequences of alternative actions. An emergent situation is one in which (1) all action-relevant environmental conditions have not been specified, (2) the state of the system does not correspond to relied-upon predictions, and (3) analytic solutions are not available, given the current state of analytic technology.

Note that there is actually a continuum of situations in which the end points can be described as established or emergent.

The emergent/established distinction is of particular importance here, since it is the emergent situation which a number of investigators think is especially appropriate for team training. Wagner et al. (1977) notes that providing skills to deal with emergent, unstructured situations is seen as a major goal of team training, and that an emergent situation permits a more realistic, less abstract approach to the investigation of team training variables than does the established situation. Popelka and Knerr (1980) state that "...team training in communications and other interactive skills is valuable when tasks require such skills, when the work situation is emergent, and when task requirements are highly complex.

One concludes that emergent situations are the primary task environments for team training research.

TRAINING SEQUENCE

The most effective method of sequencing of training has been a long-standing issue. One of the more prominent issues--whether individual training should precede team training or the other way around--will not be treated here, since the principle of individual training first is well established in the Navy. There is, of course, supporting evidence that team training given before individual proficiency has been achieved may, in fact, cause a decrement in individual proficiency (Horrocks et al., 1960).

Otherwise, there are a number of offers of guidance in this matter presented in the literature:

Kanarick (1971) proposed three phases for team training: "Initially, there is the need to train individuals in the procedural aspects of their jobs, doctrine, and the process approach to decision making. This training should be followed by a phase in which team members are instructed as a unit, learning the interactive and communicative requirements of team functioning. The final phase is devoted to tactical training where teams are taught to apply their procedural and interactive skills to certain situations requiring innovative and creative behaviors."

Jeantheau (1969) presents four basic principles:

1. Training objectives are specified across the range of device capability.

2. Each exercise is structured and controlled with respect to those specified objectives.

3. Training involves a systematic progression through the objectives according to levels of difficulty.

4. The progression through the sets of exercises is sensitive to, and guided by, measured trainee performance.

With regard to progression through levels of difficulty, Hall and Rizzo (1975) cite the work of Smode (1972) indicating a number of methods to manipulate problem difficulty:

1. Easy to hard continuum (e.g., continual increase in the events provided).

2. Procedural to fully integrated continuum (e.g., later exercises emphasize full utilization of portions of system used only procedurally in earlier exercises).

3. Increasingly stringent conditions of performance (e.g., winds, speeds, etc.).

4. Increasingly stringent error tolerances (e.g., precision demanded).

5. Amount of stimulus support (prompts, cues, KOR, etc.).

While the literature is in substantial agreement about the appropriateness of sequencing training through an easy-hard continuum, the actual design is somewhat of an art form. It appears that empirical tests of alternative sequences are in order, circumstances permitting.

PERFORMANCE MEASUREMENT

The requirement to provide feedback and to sequence training based on performance leads directly to the requirement for a performance measurement system. As Hall and Rizzo (1975) specify: "What is needed for team training is an objectively based performance measurement system. This should consist of performance standards and means for obtaining, processing, and comparing student 'scores' to the standards for arriving at summary evaluations and for giving student feedback on how well he is doing during training."

However, while individual and collective performance may lead directly from systems analysis methods, measures of team phenomena do not. Simply stated, we do not know what is accomplished during team training. Hall and Rizzo (1975) comment that "While everyone professes intuitively to be able to recognize a good team--the 'I'll know it when I see it' phenomena--no one seems able to articulate its dimensions with sufficient clarity to permit the development of training procedures for producing it." And further: "Apparently, the operational squadrons feel that the individuals sent to them from the team training program are not yet ready to function within a team. It is felt that 'something' has not been achieved that is needed for effective team functioning."

In view of this uncertainty about quantifiable aspects of team phenomena, it would appear that exploratory research is in order to search for meaningful measures.

APPENDIX D

HIGH LEVEL KNOWLEDGE OF THE ASWOC

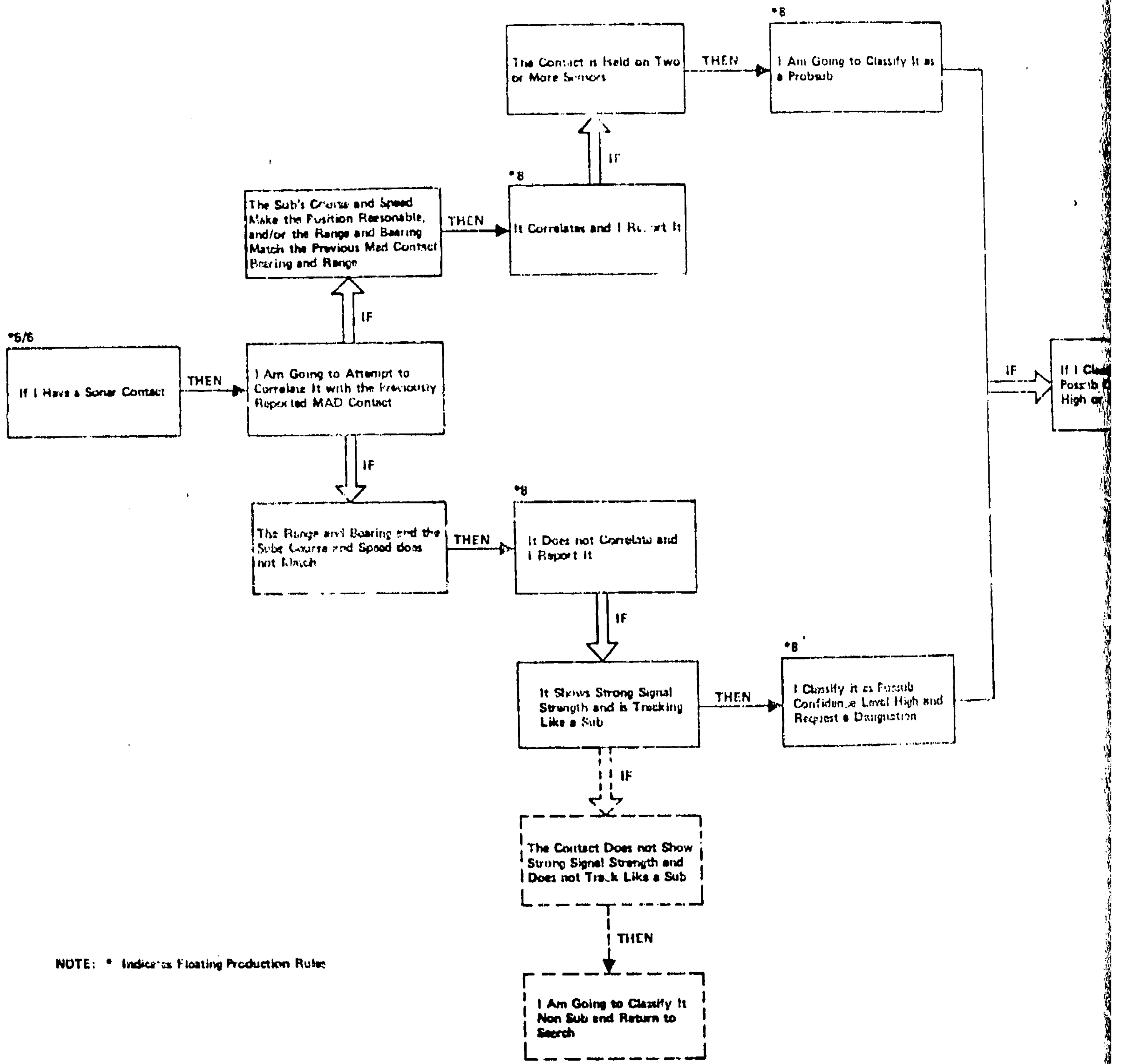
In order to develop a knowledge representation architecture and control structure for the team member models, it was necessary to articulate a representative sample of the knowledge and rules used in the ASW problem. For this purpose, the high level rules and knowledge employed by the ASWOC during the scenario was assembled and expressed in an "if/then" format analogous to production rules. Some of the conditions described in the rules can come about at any time, and the rules relating to these conditions have been described in table format in Table D-1. Other conditions can be organized sequentially and the related rules are shown in Figure D-1. The numbers above some of the boxes in this figure refer to the "floating" rules given previously in Table D-1 which are likely to be invoked at that point in the sequence. The dashed lines in the figure represent branches which should not be taken in the training scenario.

It should be emphasized that the rules shown in the table and figure are relatively high level rules which require further knowledge to evaluate and carry out. Therefore, each "if" on the figure might actually involve invoking many production rules to evaluate, and each "then" may require many rules to accomplish. To illustrate, one box (shown with bold outlines on page D-4) was arbitrarily chosen and analyzed in more detail. As shown in Figure D-2, the phrase "assume the duties of the attacking ship" used in this box requires invoking many rules to accomplish.

This analysis was used to aid the software designers in gaining an understanding of the quantity of information in the form of rules and procedures which the team member models will have to employ, as well as the variety of conditions which the models will have to monitor.

TABLE D-1. "FLOATING PRODUCTION RULES" WHICH THE ASWOC MAY EMPLOY AT ANY TIME DURING THE SCENARIO.

Number	IF	THEN
1	The submarine is detected within 6000 yards of any friendly unit	Conduct urgent attack
2	The ship is maneuvered	Report maneuver to the SAU
3	A weapon is prepped	Report weapon prep to SAU
4	It is necessary to adjust sectors	Adjust sectors
5	The range and bearing to the contact is known	Report to SAU at least once per minute
6	The course and speed of the submarine is known	Report to SAU and all stations
7	A weapon is fired	Report to SAU with firing bearing
8	The ASWOC is going to communicate externally	Select radiotelephone position on the console communication panel, depress footkey, talk
9	The ASWOC is going to communicate with the ASWFCO	Select the 1JS position on the console communications panel, depress the footkey, talk
10	The ASWOC is going to communicate with the ASAC	Select interphone position on the console communications panel, depress the interphone button for ASAC, wait for an acknowledgement, depress footkey, talk
11	A track symbol or point is to be hooked	Depress ball tab enable, roll the ball tab over the symbol or point, depress hook FAB, watch for the circle to appear around the symbol or point and the DRO to change



NOTE: * Indicates Floating Production Rules

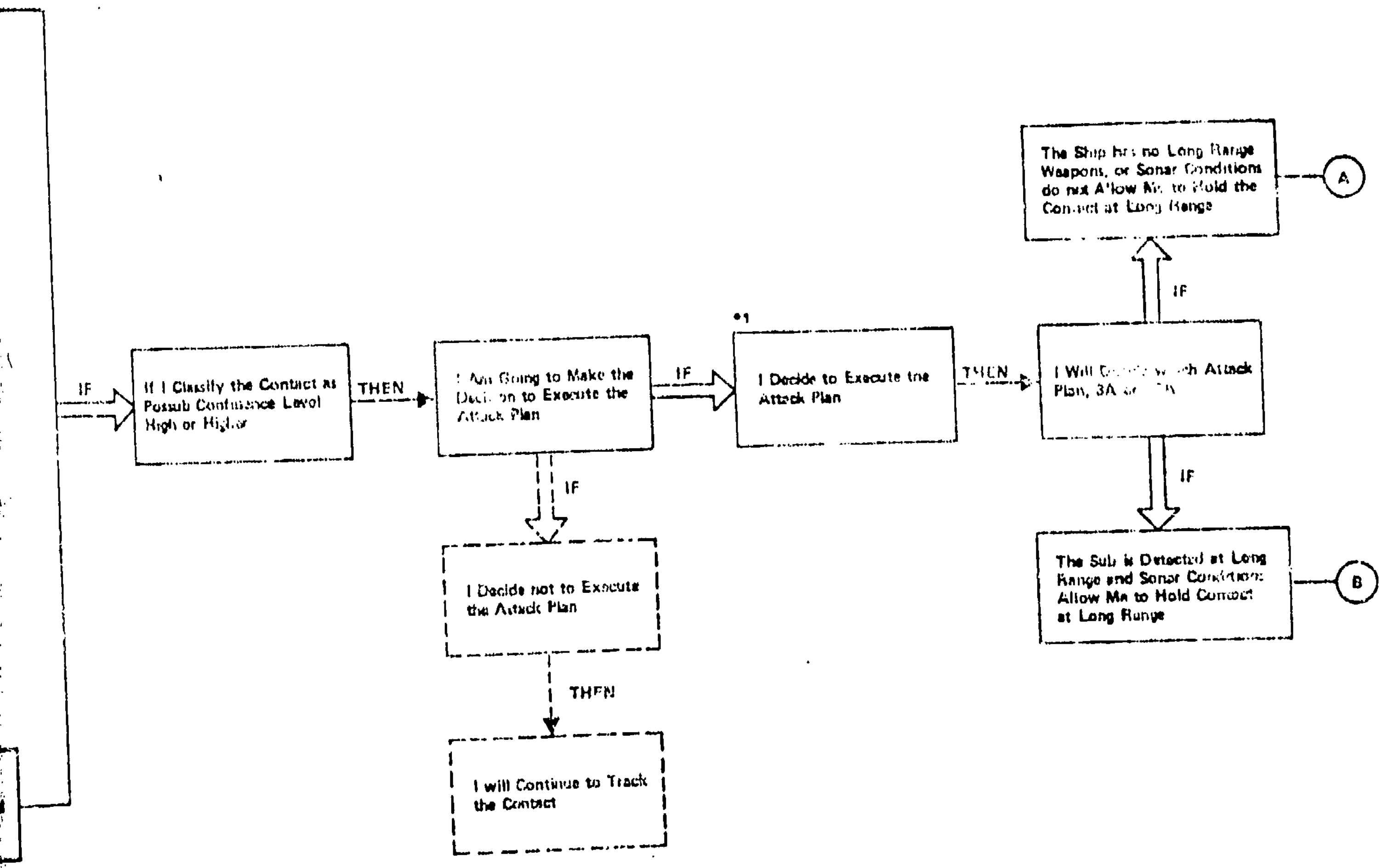
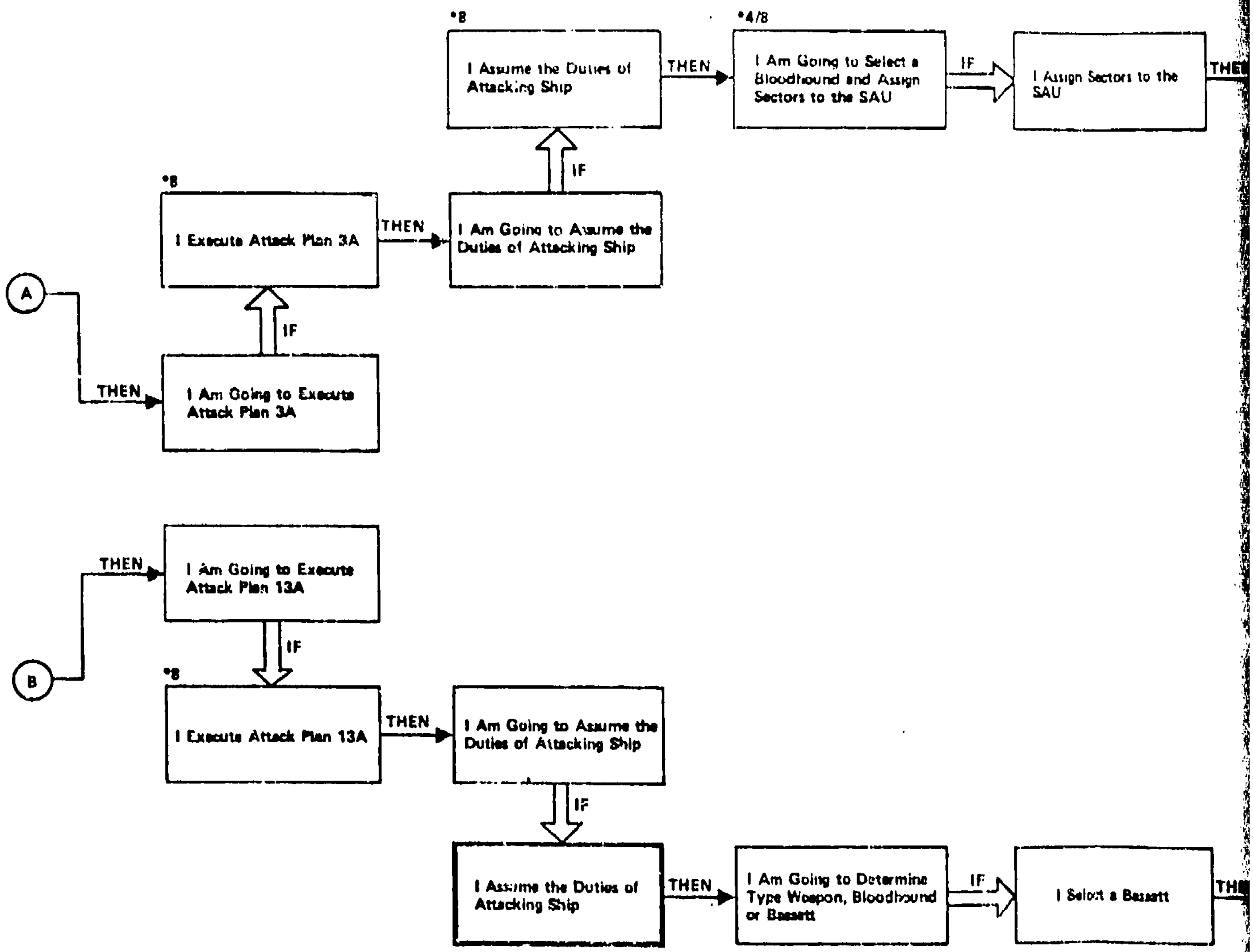


Figure D-1. High Level Knowledge of the ASWOC



NOTE: * Indicates Floating Production Rules

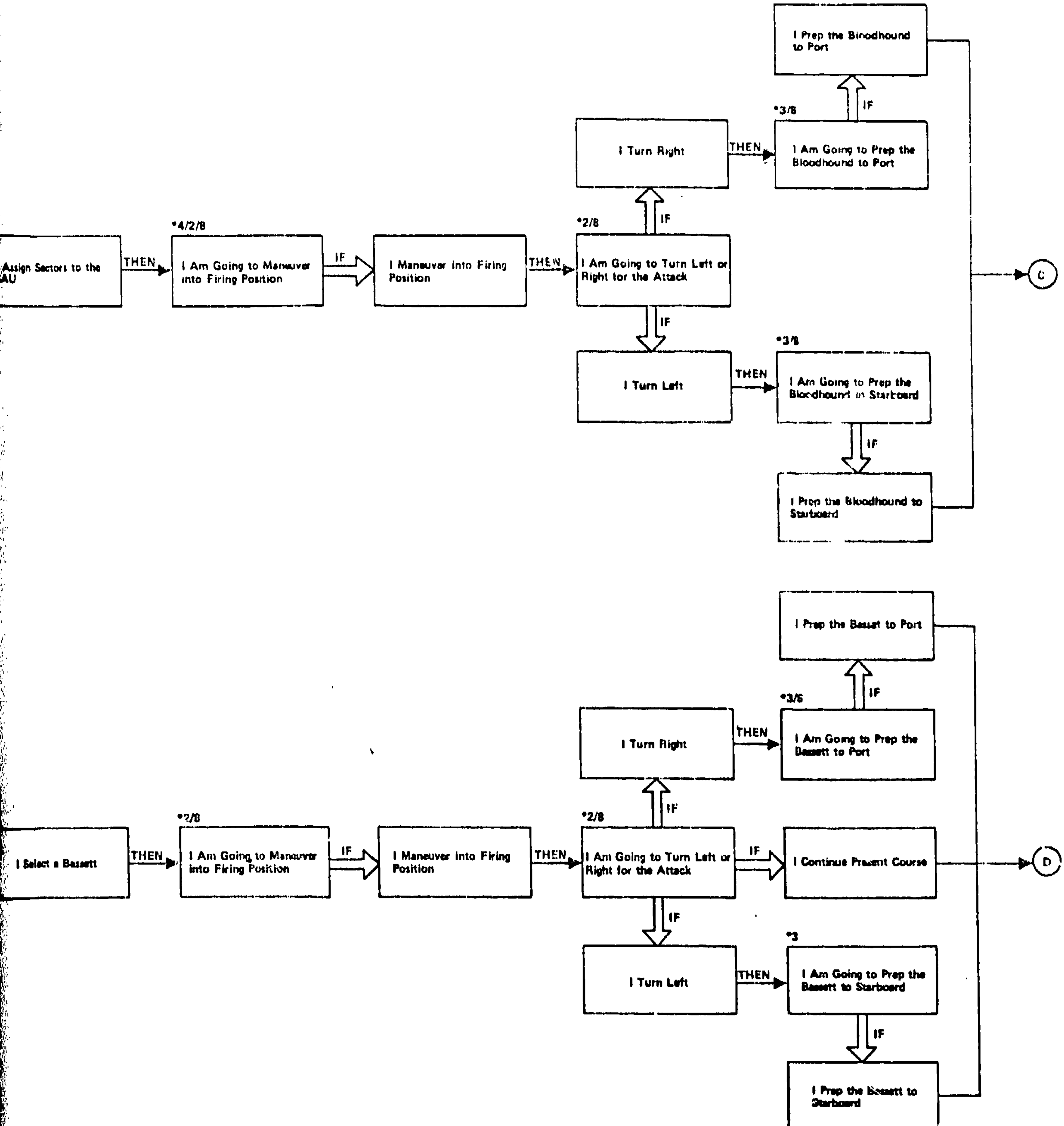
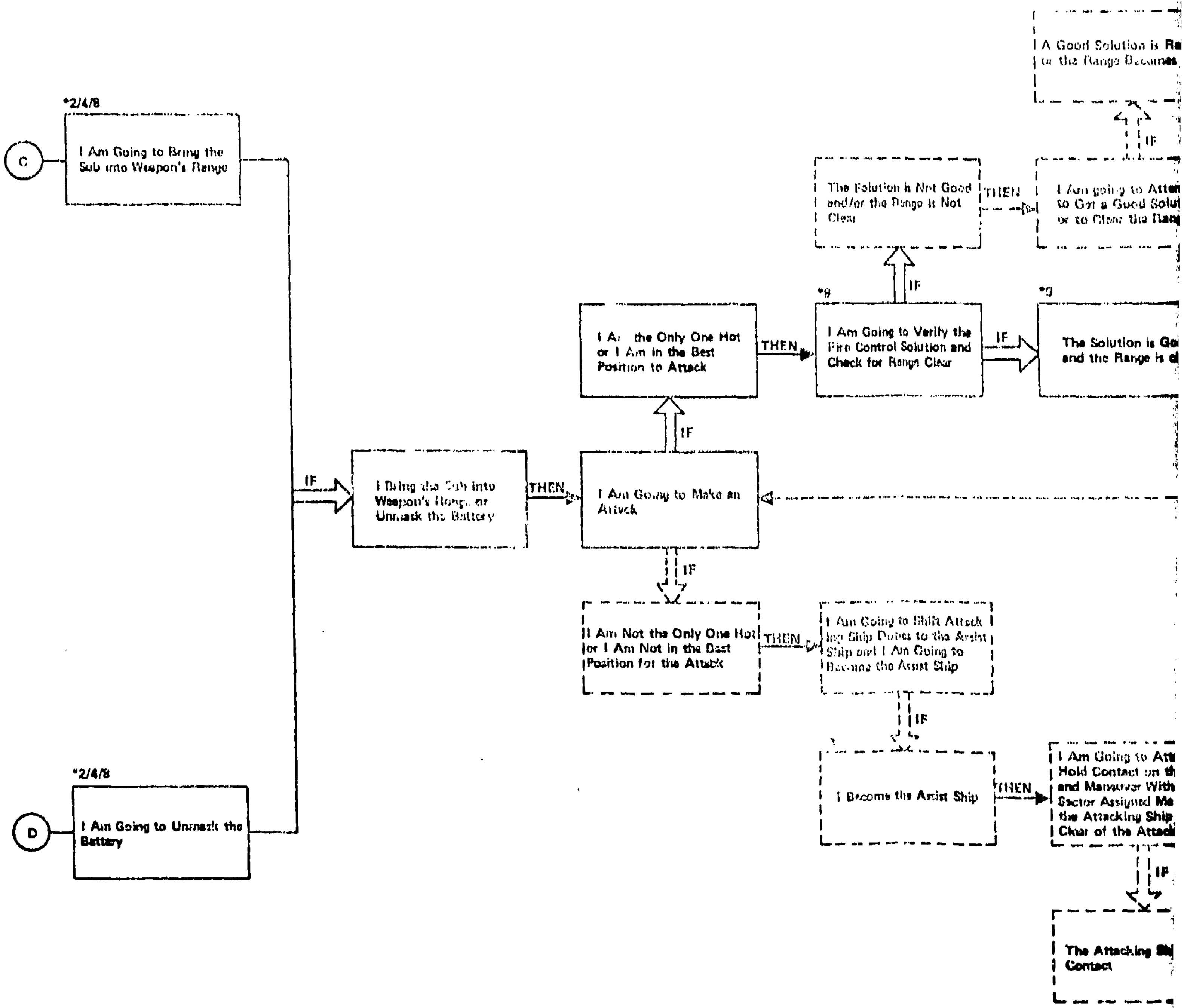


Figure D-1. High Level Knowledge of the ASWOC, continued.



NOTE: * Indicates Floating Production Rules

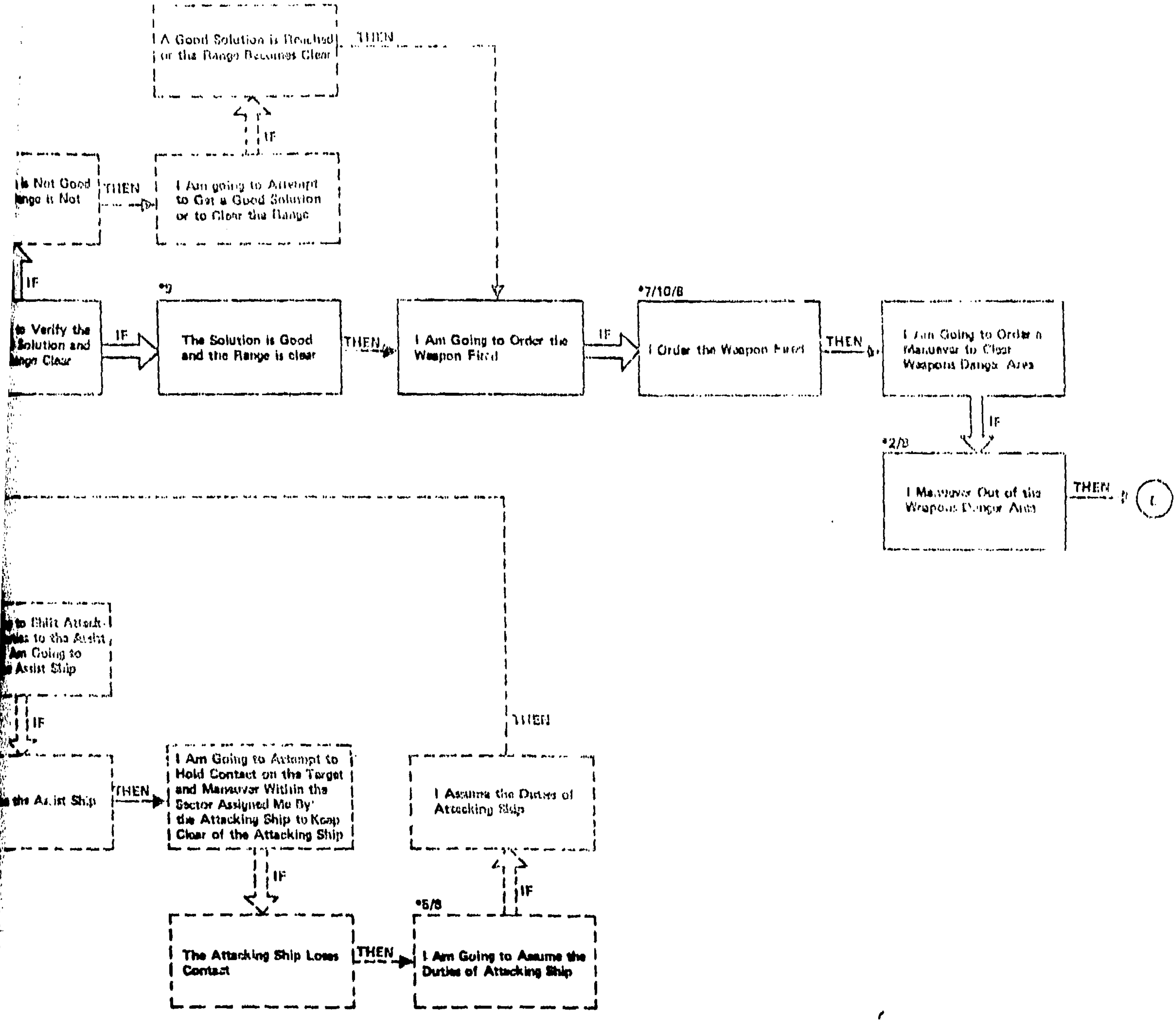
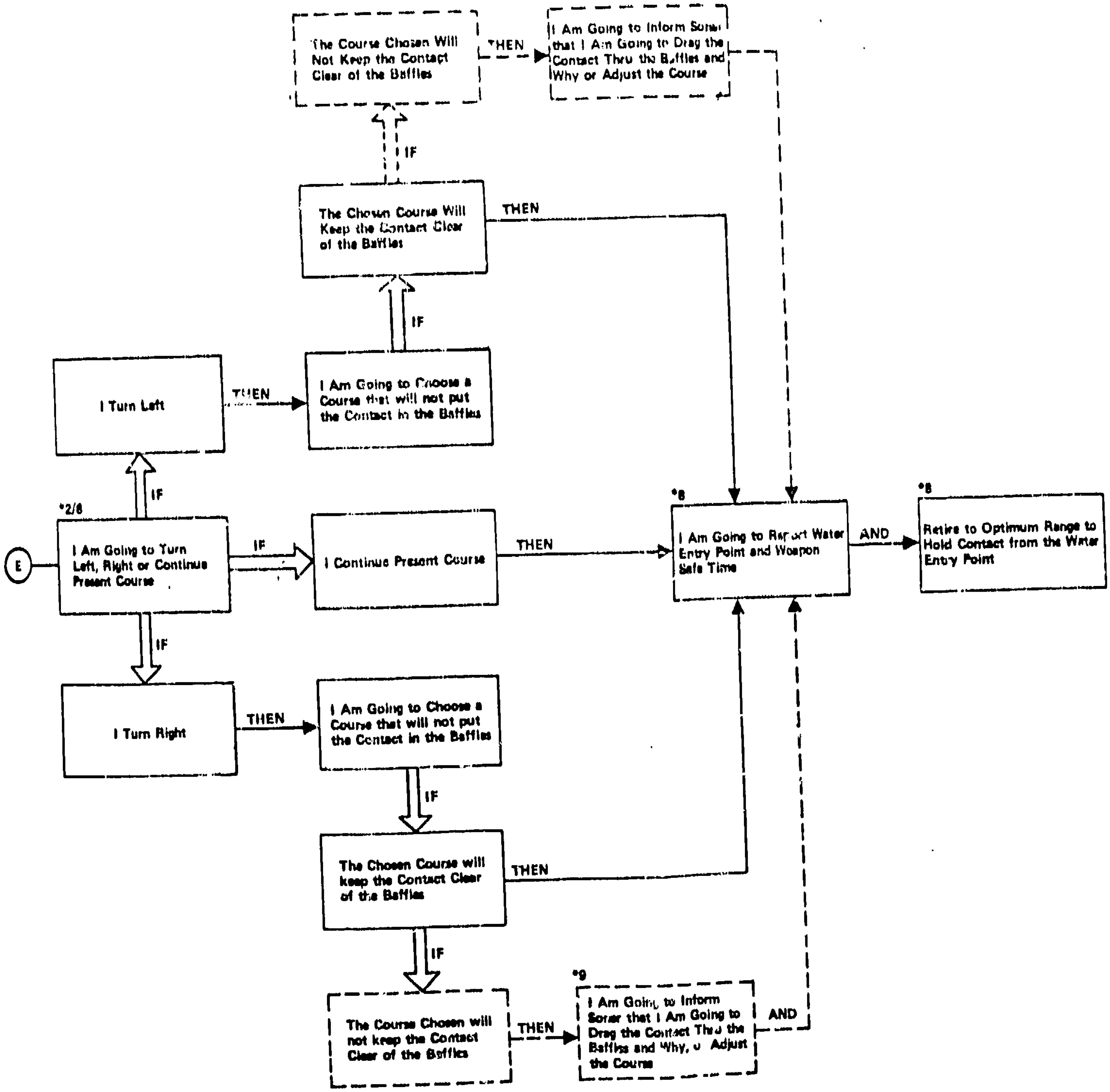
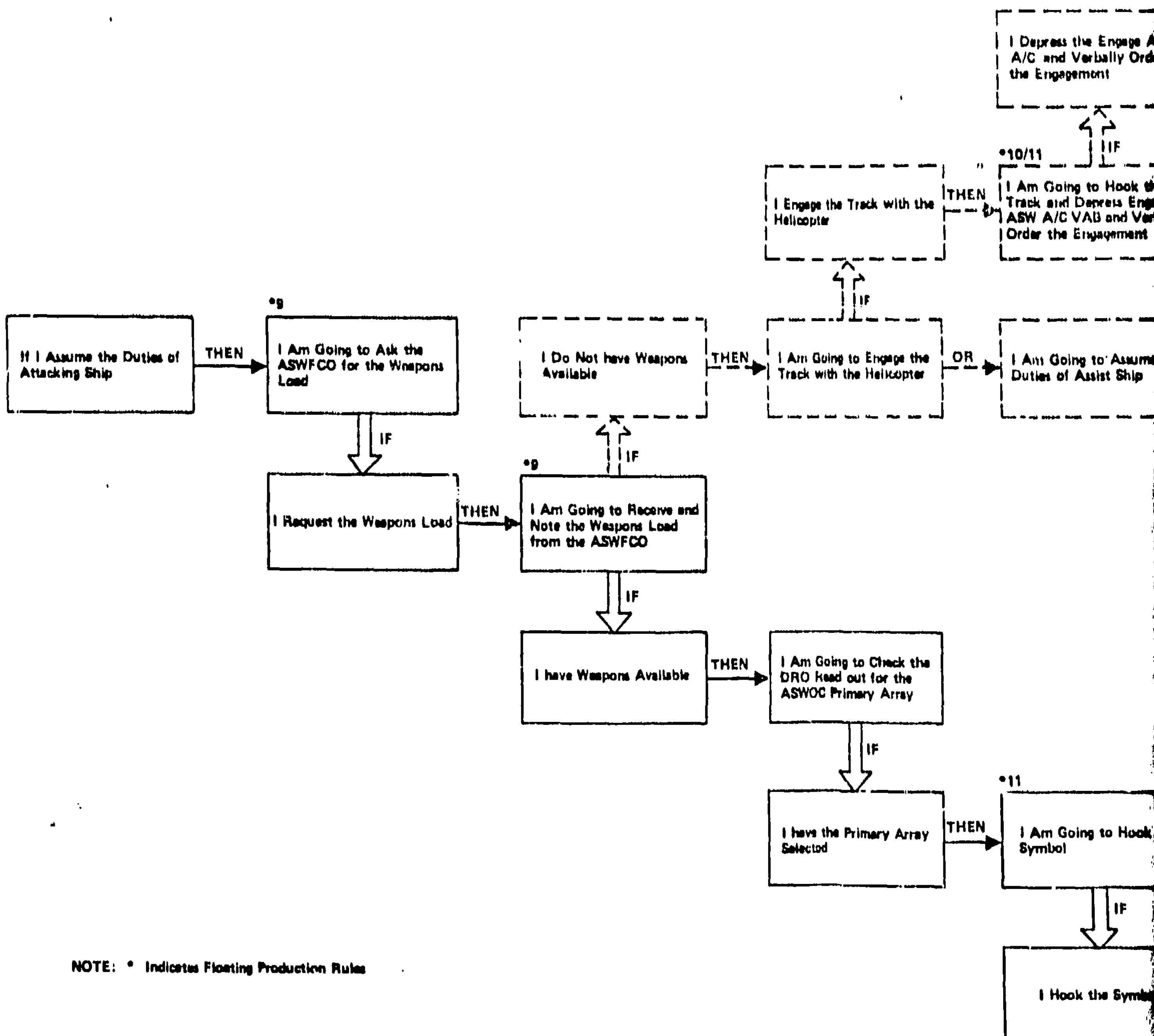


Figure D-1. High Level Knowledge of the ASWOC, continued.



NOTE: * Indicates Floating Production Rules

Figure D-1. High Level Knowledge of the ASWOC, continued.



NOTE: * Indicates Floating Production Rules

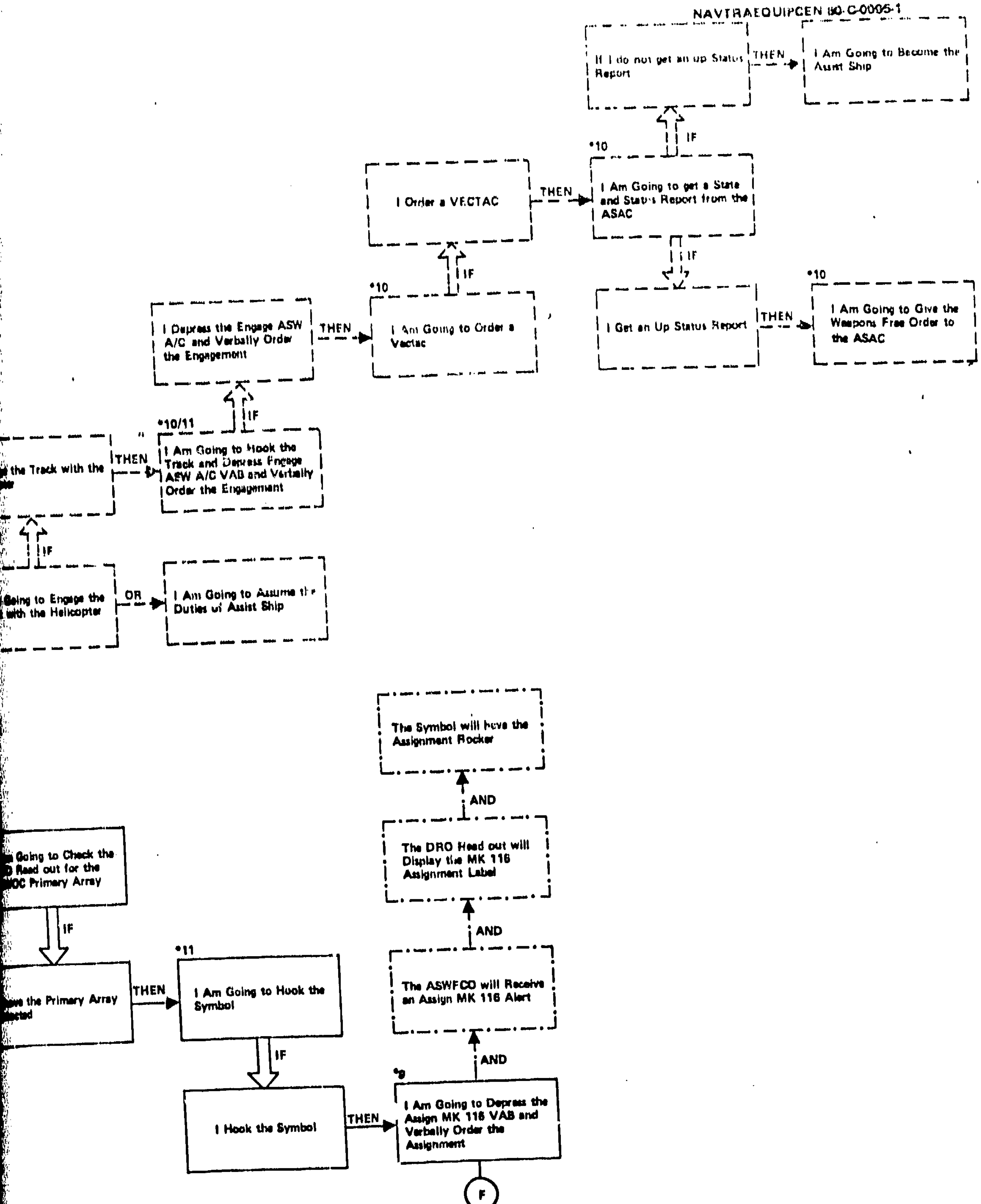
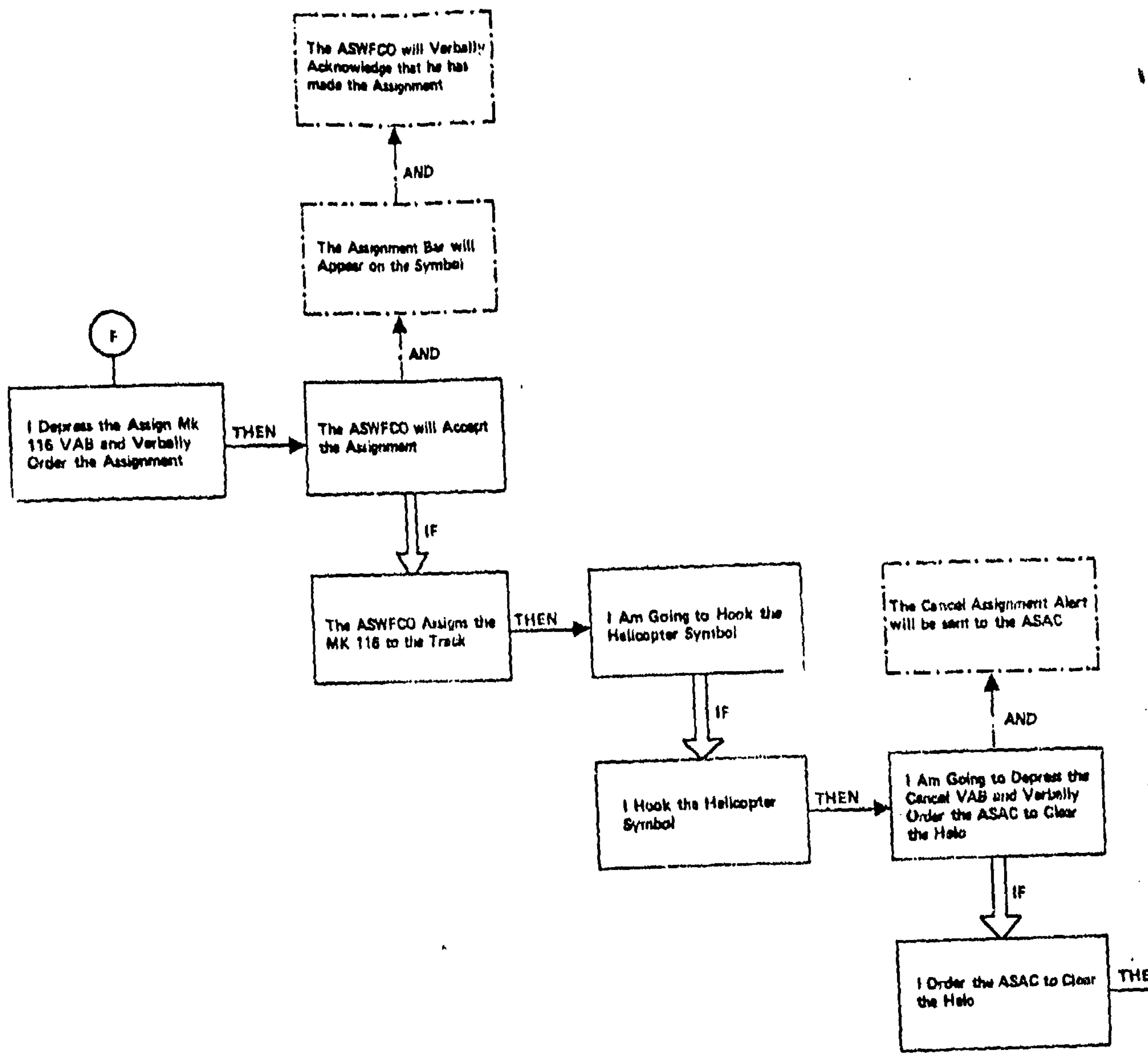


Figure D-2. Amplification of ASWOC Knowledge



NOTE: * Indicates Floating Production Rules

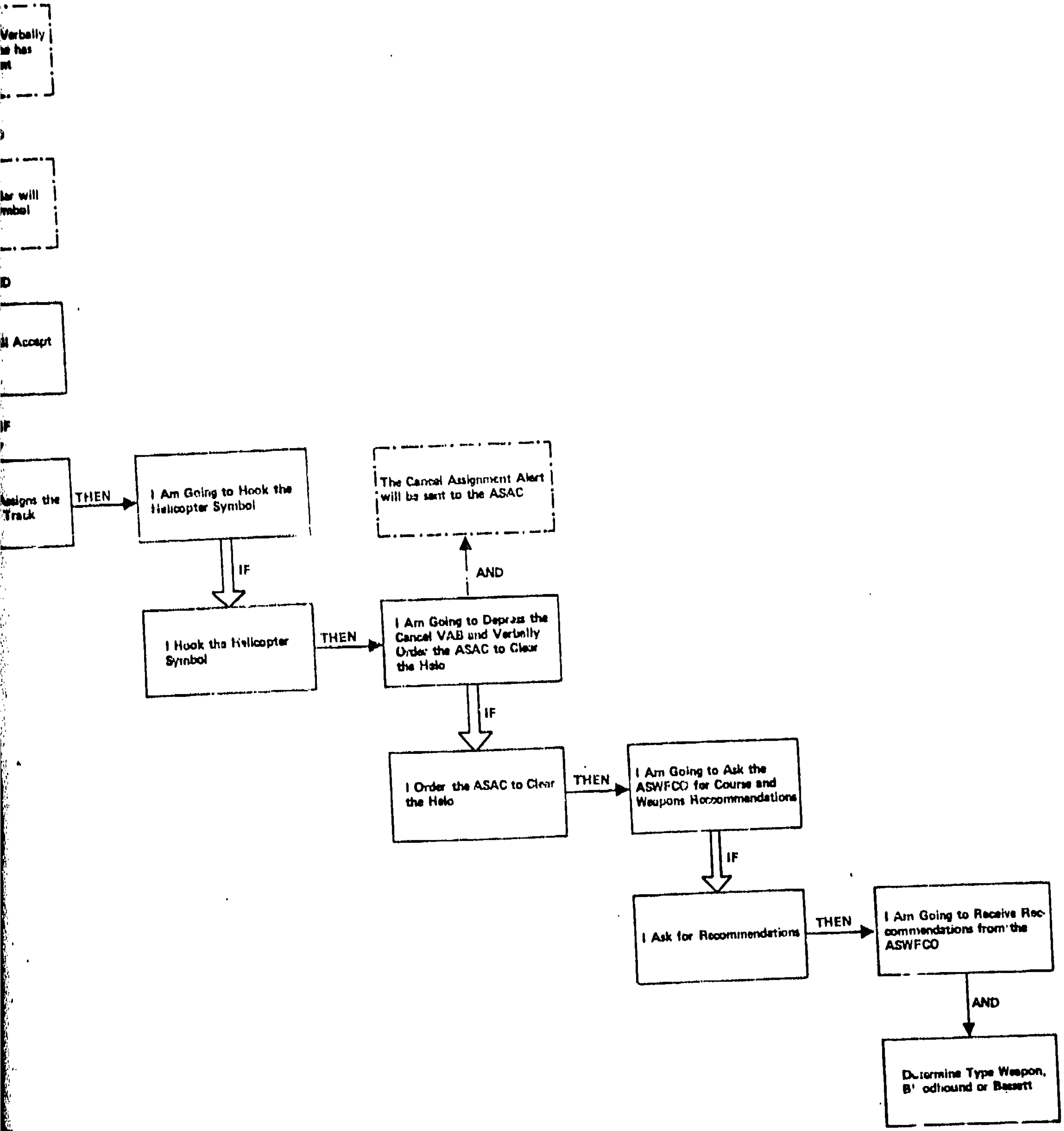


Figure D-2. Amplification of ASWOC Knowledge, continued.

APPENDIX E

TRAINING CONSOLE CAPABILITIES

In order to perform their tasks, the members of the ASW team must utilize the NTDS console and the ASWFCO must also utilize a separate weapons control panel. While look-alike consoles are not necessarily required for the ASW team training system, the functions provided by the consoles must be available. For this reason, a description of the relevant functional characteristics of these consoles, derived from the Systems Operator's Manual for DD963 Class, PD(A)-06166, is provided in the paragraphs which follow. Because the scenario proposed for the initial implementation focuses upon one aspect of ASW, only a subset of the console capabilities will be required. These required capabilities are noted in the descriptive tables which follow.

THE NTDS CONSOLE

In general, the NTDS console serves a variety of functions: it provides a radar display, and display of digital information on the digital read out (DRO). In addition, the operator can use the various buttons to request information and perform calculations, and to update the data base.

The NTDS console has a limited number of buttons which are used to provide a very large range of functions. To accomplish this, the console provides a few fixed action buttons (FABs), which always have the same effect, and a set of variable action buttons (VABs) whose function depends upon which "array" or set of button meanings is activated. In addition, the Digital Data Entry Unit (DDEU) allows numerical input.

The fixed action buttons, shown in Table E-1, and the DDEU inputs, shown in Table E-2, are used by all three team members. The different variable action buttons used by each team member are described in the paragraphs which follow.

ASWOC CONSOLE FUNCTIONS

The ASWOC's mode selection capability is shown as an array tree in Figure E-1. Of the possibilities shown, the training system scenario requires that the ASWOC use the ASWOC primary array (shown simply as "ASWOC" in the figure), the ASWOC alternate array (ALTN ASWOC), and the ASW data array (ASW DATA).

The ASWOC primary array, shown in Figure E-2, is used to assign weapons, engage targets, cancel assignments, and perform other control functions. A brief description of the function of the VABs in this array is given in Table E-3. In this and in the following tables, the VABs needed in the training scenario are marked with an asterisk.

The ASWOC alternate array, shown in Figure E-3, is used to gain additional information and to update the data base. A brief functional description of the VABs in this array is provided in Table E-4.

The ASW data array, shown in Figure E-4, is used to acquire information to aid the decision making process. A description of these VABs is provided in Table E-5.

TABLE E-1. FIXED ACTION BUTTONS AVAILABLE TO ASWOC, ASAC, AND ASWFCO.

FAB	Function
1	Array Select
2	Array Sequence
3	Sequence
4	Enter Offset
5	Pointer*
6	Drop Track
7	Track Number
8	Height
9	Rolling Ball Tab
10	Ball Tab
11	Ball Tab Enable
12	Hook
13	Center

* Not available to the ASAC.

TABLE E-2. SENSOR CODES FOR DDEU ENTRY.

DDEU	Value	Sensor
5	1	Ownship Active Sonar Channel 1
5	2	Ownship Active Sonar Channel 2
5	3	Ownship Passive Sonar Channel 1
5	4	Ownship Passive Sonar Channel 2
5	5	Remote Ship Active Sonar
5	6	Remote Ship Passive Sonar
5	7	Helo Active Sonar
5	8	Helo Passive Sonar
4/5	9	Active Sonobuoy
4/5	10	Passive Sonobuoy
4/5	11	Visual
4/5	12	Radar
4/5	13	MAD
4/5	14	LOFAR
4/5	15	Intelligence
4/5	16	ESM
4/5	17	CASS
4/5	18	DIFAR
4/5	19	DICASS
4/5	20	Ownship Sonar Unit 31
4/5	21	FLIR

TABLE E-2. SENSOR CODES FOR DDEU ENTRY, CONT.

DDEU	Value	Sensor
4/5	22	Wideband/Acoustic

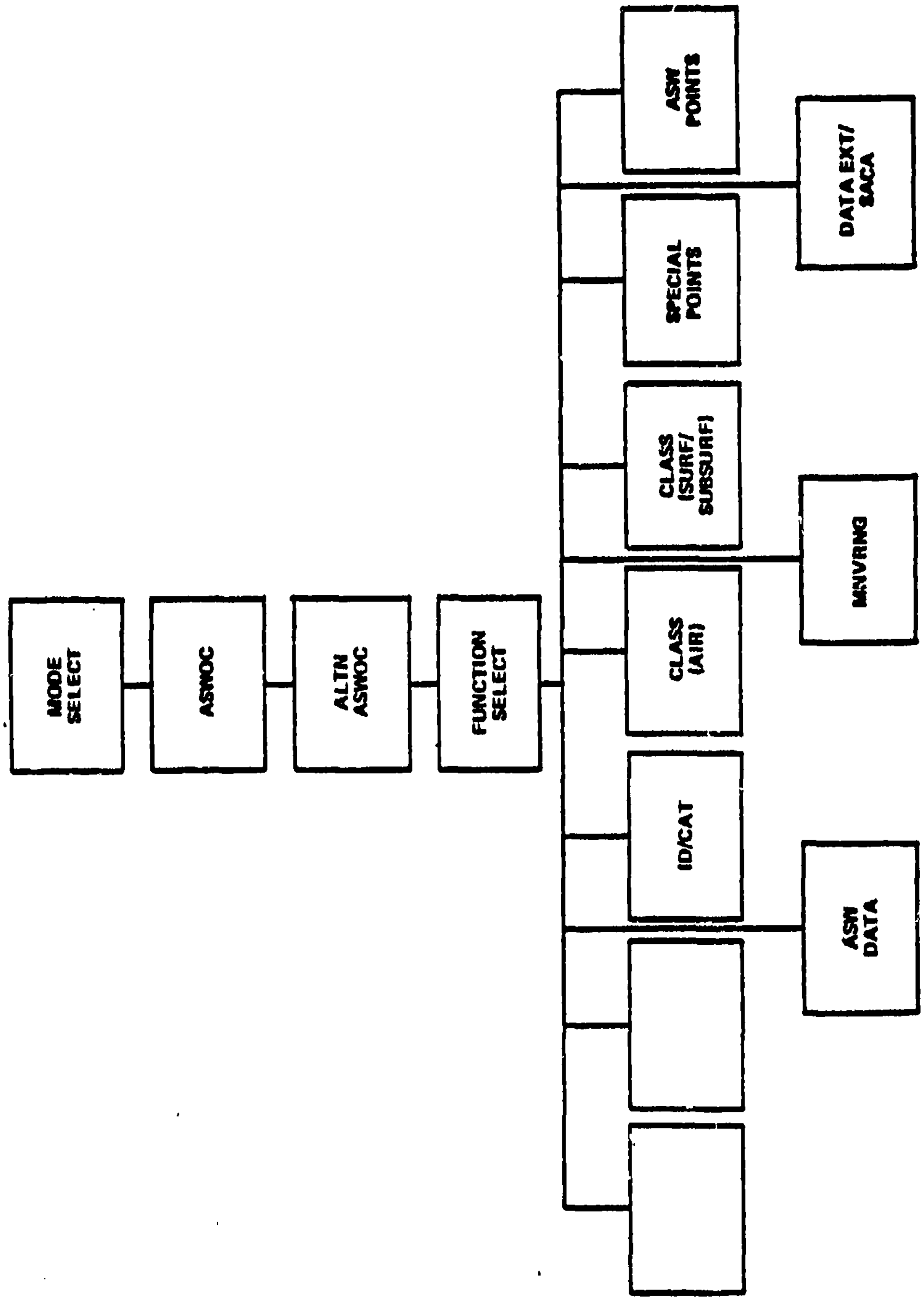
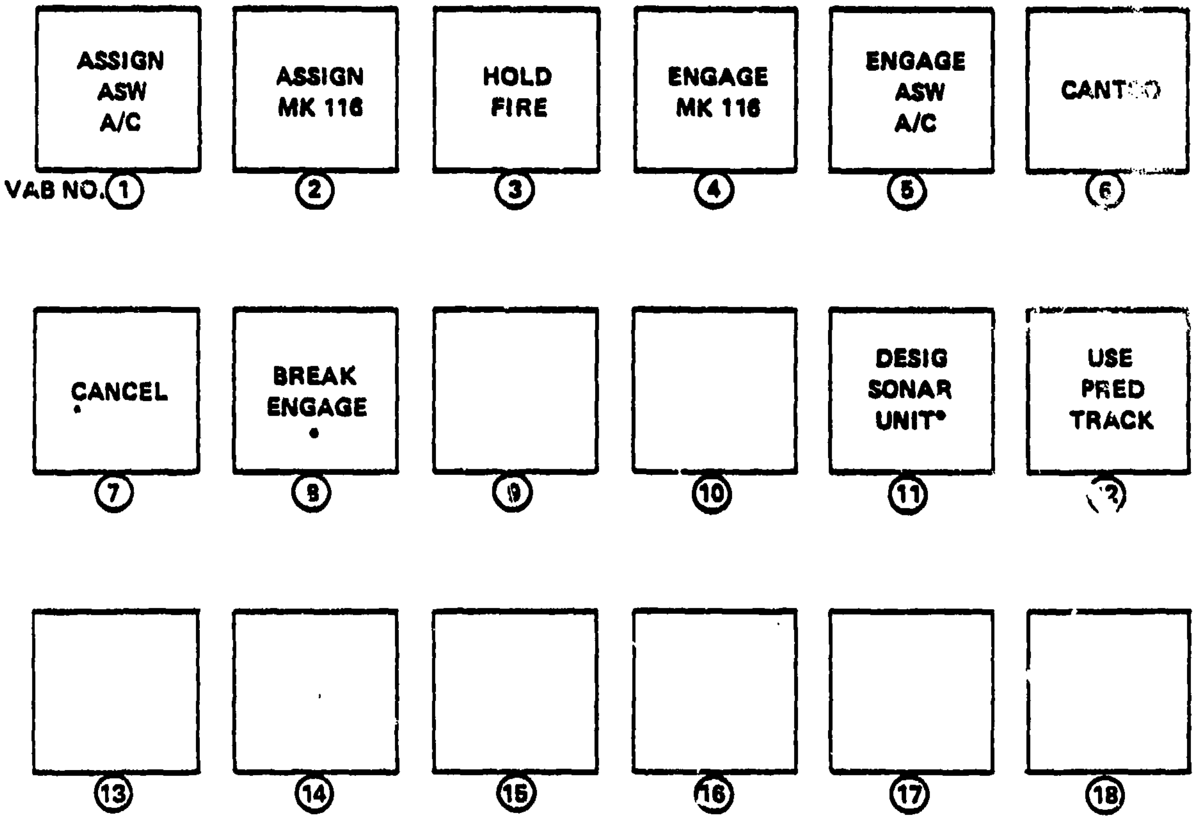


Figure E-1. ASWOC array tree.



*Indicates a DDEU entry accompanies the VAB action.

Figure E-2. ASWOC primary array.

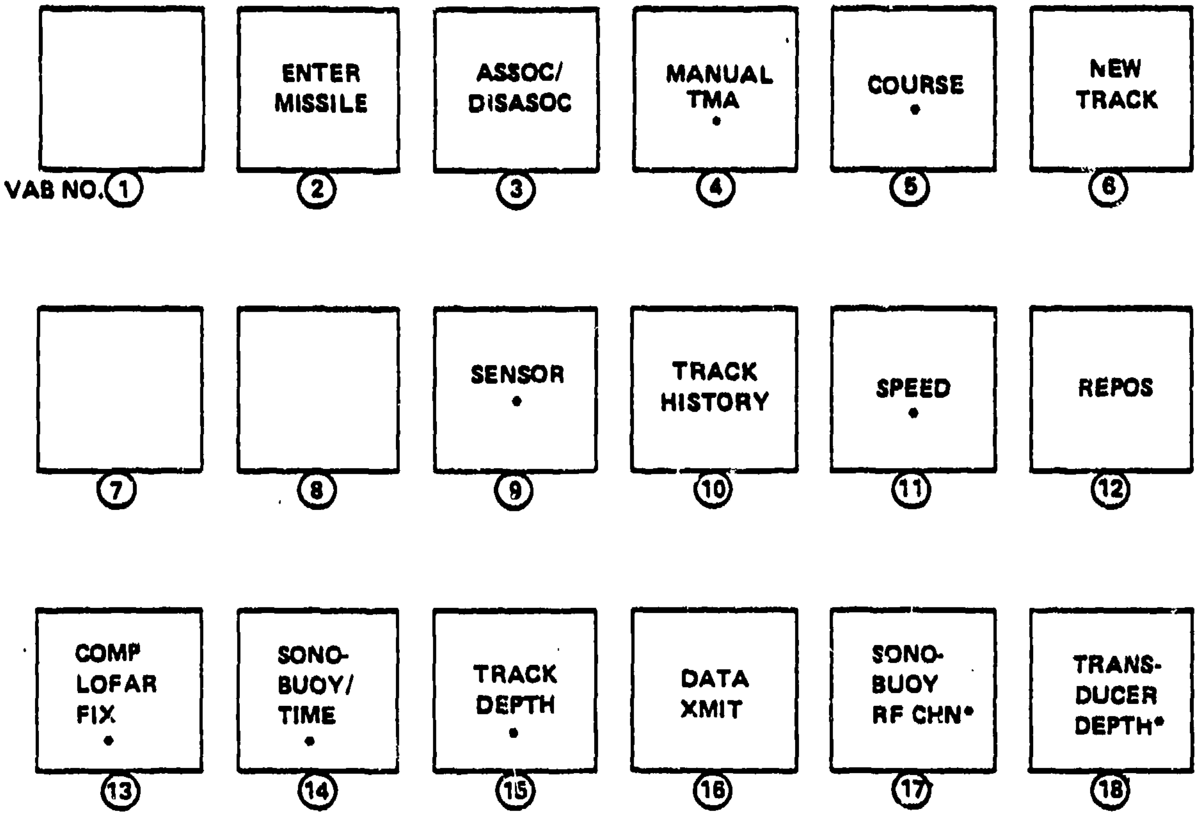
TABLE E-3. ASWOC PRIMARY ARRAY FUNCTIONS.

VAB	Label	Function Summary
1*	ASSIGN ASW AC	Orders ASAC to assign an ASW aircraft to the track in close control.
2*	ASSIGN MK 116	Orders ASWFCO to assign the track in close control to the Mk 116.
3*	HOLD FIRE	Alerts the ASWFCO and/or ASAC to hold fire on the track in close control.
4*	ENGAGE MK 116	Orders ASWFCO to engage the track in close control with a weapon of his choice.
5*	ENGAGE ASW AIC	Orders ASAC to engage the track in close control with a weapon of his choice.
6	CANTCO	Notifies SWC that ASWOC cannot comply with an engagement or assignment order.
7*	CANCEL	Terminates an assignment currently in progress.
8*	BREAK ENGAGE	Orders ASWFCO or ASAC or both to break all engagements against the track in close control.
9	9	Not implemented.
10	10	Not implemented.
11*	DESIG SONAR UNIT	Orders a sonar to search a designated position for a contact.
12*	USE PRED TRACK	Orders use of, or termination of, predicted track data for a contact.
13	13	Not implemented.
14	14	Not implemented.

* Function required in the training scenario.

TABLE E-3. ASWOC PRIMARY ARRAY FUNCTIONS, CONT.

VAB		Label	Function Summary
15	15		Not implemented.
16	16		Not implemented.
17	17		Not implemented.
18	18		Not implemented.



*Indicates a DDEU entry accompanies the VAB action.

Figure E-3. Alternate ASWOC array.

TABLE E-4. ASWOC ALTERNATE ARRAY FUNCTIONS.

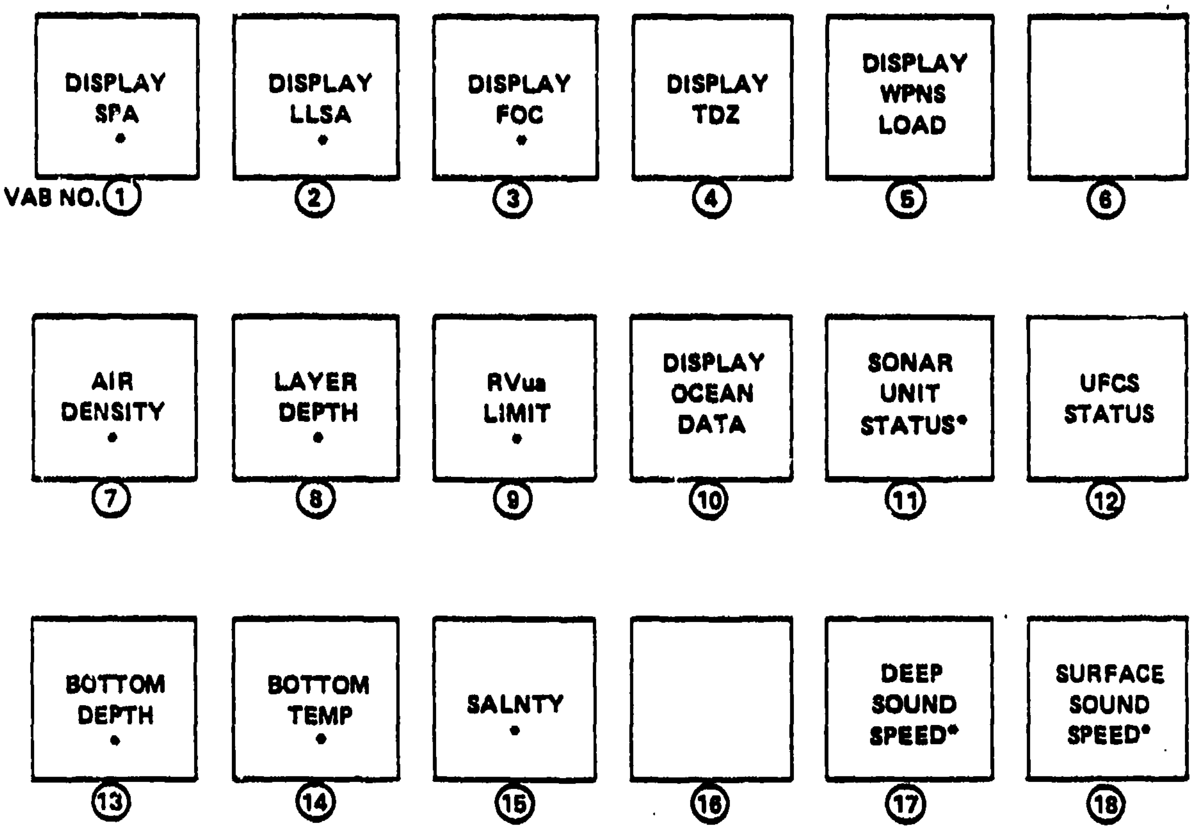
VAB	Label	Function Summary
1	1	Not implemented.
2	ENTER MISSILE	Enters a new hostile missile track at the ball tab coordinates, and, if a track is in close control, changes that parent to a missile platform.
3*	ASSOC/DISSOC	Associates or disassociates two specified OSS tracks.
4	MANUAL TMA	Initiates a manual TMA override for an OSS track or terminates manual TMA override for an OSS track or PK track.
5*	COURSE	Enters a manual value for course on the specified UFCS-reported (OSS Mk 116 manual subsurface) track or ownship when specified.
6	NEW TRACK	Manually enters a Mk 116 manual subsurface track at the specified coordinates.
7	7	Not implemented.
8	8	Not implemented.
9*	SENSOR	Enters or changes the sonar source for a specified surface or subsurface track.
10*	TRACK HISTORY	Displays track history points for specified OSS tracks or ownship (max 2).
11*	SPEED	Enters a manual value for speed on the specified UFCS-reported (OSS or Mk 116 manual subsurface) track or ownship.
12*	REPOS	Repositions the specified UFCS-reported (OSS or Mk 116 manual subsurface) track to the position of the ball tab.

* Function required in the training scenario.

TABLE E-4. ASWOC ALTERNATE ARRAY FUNCTIONS, CONT.

VAB	Label	Function Summary
13	COMP LOFAR FIX	Displays or deletes a comparative LOFAR fix.
14	SONOBUOY TIME	Enters a sonobuoy special point and associated data of type, time remaining, and holding or not holding contact.
15*	TRACK DEPTH	Enters a manual depth or use doctrine value for depth (440 ft.) on the specified UFCS-reported (OSS or Mk 116 manual subsurface) track.
16	DATA XMIT	Initiates LINK-11 transmissions of a specified OSS track or local acoustic bearing line.
17	SONOBUOY RFCHN	Enters the radio frequency (RF) channel for a specified sonobuoy.
18	TRANSDUCER DEPTH	Enters the transducer depth of a specified sonobuoy.

* Function required in the training scenario.



*Indicates a DDEU entry accompanies the VAB action.

Figure E-4. ASW data array.

TABLE E-5. ASW DATA ARRAY FUNCTIONS.

VAB	Label	Function Summary
1*	DISPLAY SPA	Request or delete the display or submarine's probability area.
2*	DISPLAY LLSA	Request or delete the display of limiting lines of submerged approach.
3*	DISPLAY FOC	Request or delete the display of the furthest on circle.
4*	DISPLAY TDZ	Request or delete the display of the torpedo danger zone.
5*	DISPLAY WPNS LOAD	Sequentially displays the weapon load of each cell of the ASROC launcher and the OTS torpedo tubes.
6*	6	Not implemented.
7	AIR DENSITY	Enters and displays in the DRO the value of the air density to be used.
8**	LAYER DEPTH	Enters and displays in the DRO the value of layer depth to be used.
9	RVua Limit	Enters and displays in the DRO the value of RVua limit to be used.
10*	DISPLAY OCEAN DATA	Request display of the OCEAN DATA in the DRO.
11*	SONAR UNIT STATUS	Request display of the SONAR UNIT STATUS in the DRO.
12*	UFCS STATUS	Request display of the ASW SYSTEM STATUS in the DRO.

* Function required by the ASWOC and ASWFCO in the training scenario.

** Function used by the ASWFCO in the training scenario.

TABLE E-5. ASW DATA ARRAY FUNCTIONS, CONT.

VAB	Label	Function Summary
13**	BOTTOM DEPTH	Enters and displays in the DRO the value of bottom depth to be used.
14**	BOTTOM TEMP	Enters and displays in the DRO the value of bottom temperature to be used.
15	SALNTY	Enters and displays in the DRO the value of salinity to be used.
16	16	Not implemented.
17	DEEP SOUND SPEED	Enters and displays in the DRO the value of DEEP SOUND SPEED to be used.
18	SURFACE SOUND SPEED	Enters and displays in the DRO the value of SURFACE SOUND SPEED to be used.

* Function required by the ASWOC and ASWFCO in the training scenario.

** Function used by the ASWFCO in the training scenario.

ASAC CONSOLE FUNCTIONS

The ASAC's mode selection capability is shown as an array tree in Figure E-5. Of the possibilities shown, the training system scenario requires that the ASAC use the ASAC primary array (shown simply as "ASAC" in the figure), the ASAC alternate array (ALTN ASAC), and the ASW points array (ASW POINTS).

The ASAC primary array, shown in Figure E-6, is used to control ASW aircraft and to automatically transfer information about the progress of the aircraft. These functions are described in Table E-6.

The ASAC alternate array, shown in Figure E-7, allows the ASAC to receive recommendations from the computer concerning the control of the ASW aircraft. These functions are described in Table E-7.

The ASW points array, shown in Figure E-8, is used for the entry of information such as MAD contacts and radar sinker data. The functions of these VABs are described briefly in Table E-8.

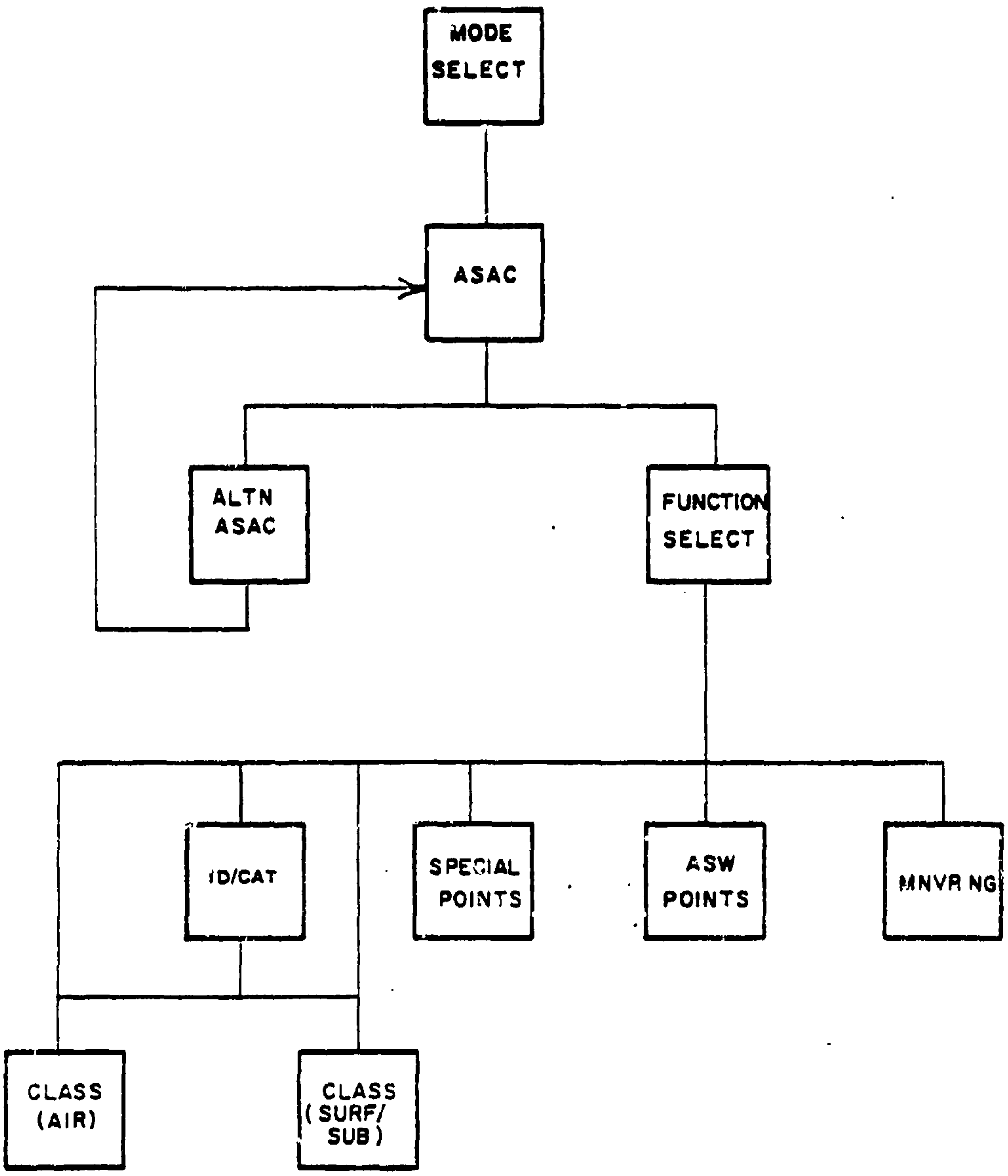
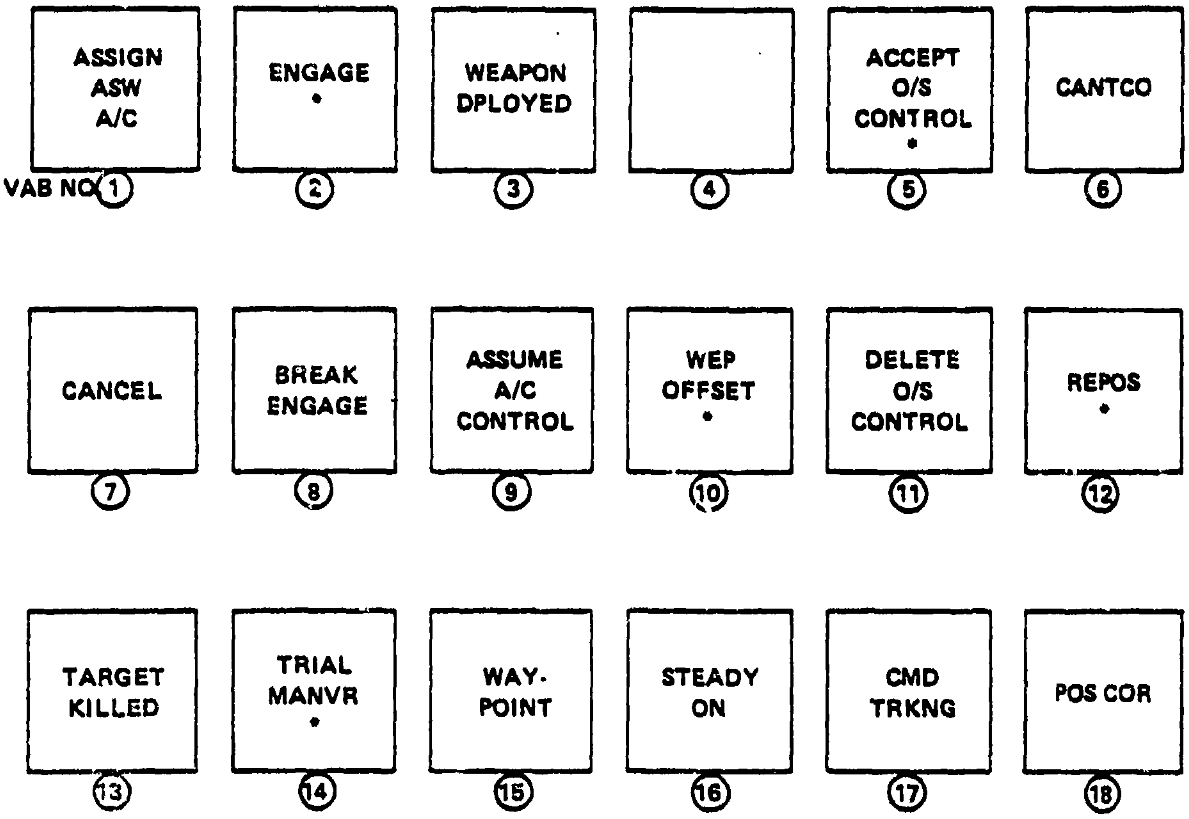


Figure E-5. ASAC array tree.



* indicates a DDEU entry accompanies the VAB action.

Figure E-6. ASAC primary array.

TABLE E-6. ASAC PRIMARY ARRAY FUNCTIONS.

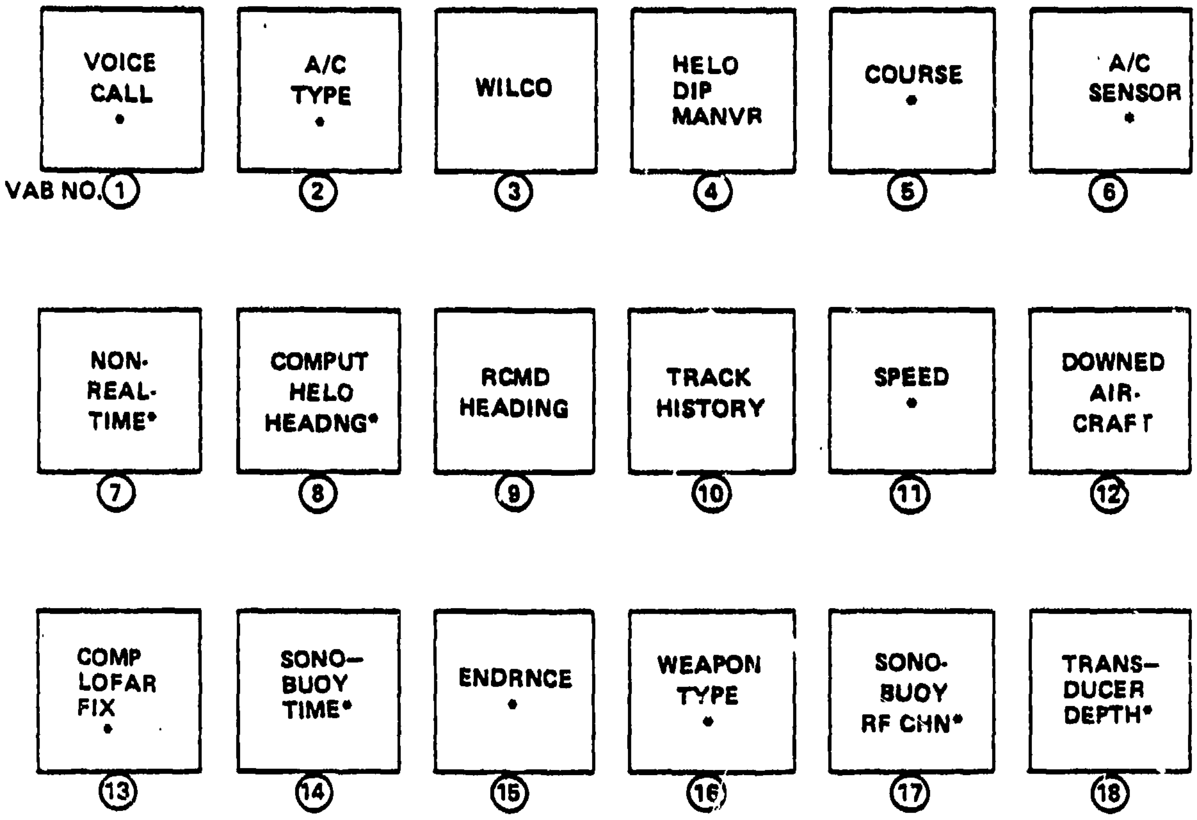
VAB	Label	Function Summary
1*	ASSIGN ASW A/C	Assigns an ASW A/C to a target.
2*	ENGAGE	Engages a target with an ASW A/C.
3*	WEAPON DPLOYED	Indicates that a weapon has been deployed by an ASW A/C.
4	4	Not implemented.
5*	ACCEPT O/S CONTROL	Designates a track or ownship controlled ASW A/C.
6	CANTCO	Responds with cannot comply to an ASSIGN. ENGAGE or ASSUME A/C control alert.
7	CANCEL	Cancels the assignment of an ownship controlled ASW A/C with a target.
8*	BREAK ENGAGE	Breaks the engagement of one or more ASW A/C with their targets.
9	ASSUME A/C CONTROL	Orders a PU to assume control of an ownship controlled ASW A/C.
10	WEP OFFSET	Modifies or deletes the modification to the WEP calculation.
11	DELETE O/S CONTROL	Deletes the designation of a track as an ownship controlled ASW A/C.
12*	REPOS	Changes the position of a track without affecting track velocity.
13	TARGET KILLED	Notifies SWC, ASWOC, and Bridge that a target was destroyed.

* Function required in the training scenario.

TABLE E-6. ASAC PRIMARY ARRAY FUNCTIONS, CONT.

VAB	Label	Function Summary
14*	TRIAL MANVR	Requests the calculation and display of a collision intercept between a track and another location.
15*	WAYPOINT	Requests modification of a Trial Maneuver to go through a specified point on the way to the intercept point.
16*	STEADY ON	Indicates that a track in command track status is at ordered heading and at ordered speed.
17*	CMD TRKNG	Enables or disables command tracking for an ownship controlled ASW A/C.
18	POS COR	Enters a corrected position for a track.

* Function required in the training scenario.



* indicates a DDEU entry accompanies the VAB action.

Figure E-7. Alternate ASAC array.

TABLE E-7. ASAC ALTERNATE ARRAY FUNCTIONS.

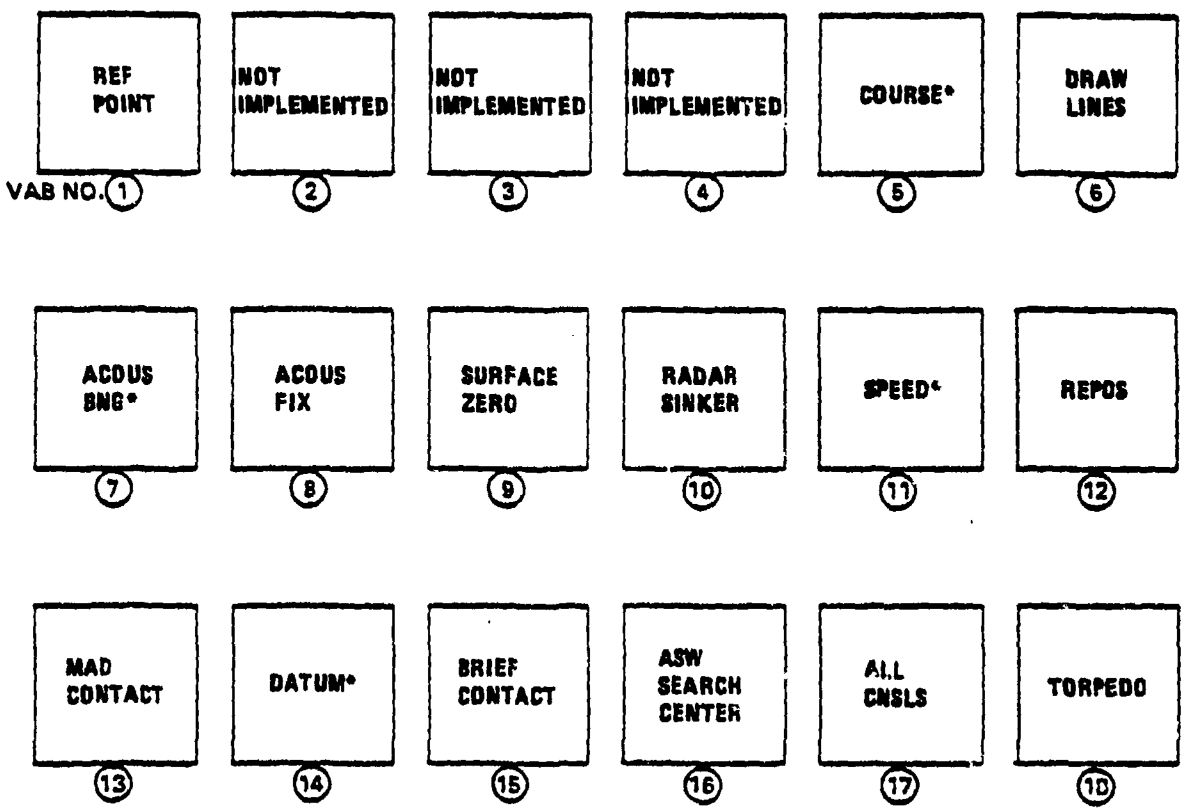
VAB	Label	Function Summary
1*	VOICE CALL	Enters or changes a voice call for an ownship controlled ASW A/C.
2*	A/C TYPE	Enters or changes the A/C type for an ownship controlled ASW A/C.
3*	WILCO	Response to assume A/C control and salvo orders.
4	HELO DIP MANVR	Initiates a helo dipping maneuver calculation and display.
5*	COURSE	Manually enters or overrides a course for a specified track.
6*	A/C SENSOR	Enters or changes any sensor status for each sensor of an ownship-controlled ASW A/C.
7	NON-REAL TIME	Enters a new firm non-real-time unknown track into the system.
8*	COMPUTE HELO HEADING	Requests the calculation of a heading and speed for a desired relative wind direction and speed across the deck for a helo launch or recovery.
9*	RCMD HEADING	Indicates to the Bridge that a recommended ownship heading and speed has been calculated for helo launch or recovery.
10*	TRACK HISTORY	Displays or deletes the display or track history points for a specified track.
11*	SPEED	Manually enters or overrides a speed for a specified track.
12	DOWNED AIRCRAFT	Enters a downed A/C symbol at the ball tab co-ordinates.

* Function required in the training scenario.

TABLE E-7. ASAC ALTERNATE ARRAY FUNCTIONS, CONT.

VAB	Label	Function Summary
13	COMP LOFAR FIX	Displays or deletes a comparative LOFAR Fix.
14	SONOBUOY/TIME	Enters a sonobuoy special point and associated data of type, time remaining, and holding or not holding contact.
15*	ENDRNCE	Enters or changes the endurance time for an ownship controlled ASW A/C.
16	WEAPON TYPE	Enters, updates, or displays the number of weapons on board an ownship-controlled ASW A/C.
17	SONOBUOY RF CHN	Enters the Radio Frequency (RF) channel for a specified sonobuoy.
18	TRANSDUCER	Enters the transducer depth of a specified sonobuoy.

* Function required in the training scenario.



*INDICATES A DDEU ENTRY ACCOMPANIES THE VAB ACTION.

Figure E-8. ASW points array.

TABLE E-8. ASW POINTS ARRAY FUNCTIONS.

VAB	Label	Function Summary
1*	REF POINT	Enters a reference point fixed special point at the ball tab coordinates.
2	2	Not implemented.
3	3	Not implemented.
4	4	Not implemented.
5*	COURSE	Enters a course value, specified in DDEUS 3, 4, and 5, for a special point or ownship.
6	DRAW LINES	Draws utility lines on the PPI. Two actions are required to draw a line, one for the beginning point and one for the ending point.
7	ACOUS BNG	Enters a non-real-time acoustic bearing on a friend surface or subsurface track. Helo or sonobuoy in close contact.
8	ACOUS FIX	Enters an acoustic fix special point at the ball tab coordinates.
9	SURFACE ZERO	Enters a surface zero special point at the ball tab coordinates.
10*	RADAR SINKER	Enters a radar sinker special point at the ball tab coordinates.
11*	SPEED	Enters a speed value, specified in DDEUs 4 and 5, for a special point or ownship.
12*	REPOS	Enters a new position for ownship or a special point in close control. The new position is specified by the ball tab position.

* Function required in the training scenario.

TABLE E-8. ASW POINTS ARRAY FUNCTIONS, CONT.

VAB	Label	Function Summary
13*	MAD CONTACT	Enters a MAD contact fixed special point at the ball tab coordinates.
14*	DATUM	Enters a Datum, changes a subsurface track to a Datum or enters, updates, or deletes alphanumeric designation of a specified Datum.
15	BRIEF CONTACT	Enters a brief contact special point at the ball tab coordinates.
16*	ASW SEARCH CENTER	Enters an ASW search center special point at the ball tab coordinates.
17	ALL CNSLS	Displays a reference point or line special point at all consoles.
18*	TORPEDO	Enters a torpedo special point at the ball tab coordinates.

* Function required in the training scenario.

ASWFCO CONSOLE FUNCTIONS

The ASWFCO's mode selection capability is shown as an array tree in Figure E-9. Of the possibilities shown, the training system scenario requires that the ASWFCO use the ASWFCO primary array (shown simply as "ASWFCO" in the figure), the ASWFCO alternate array (ALTN ASWFCO), and the ASW data array (ASW DATA).

The ASWFCO primary array is shown in Figure E-10. It allows the ASWFCO to control the ship's underwater weapons systems, and to respond to orders from the ASWOC. Using the functions in this array, the ASWFCO can put in weapons offset, can order a manual over the side (OTS) attack, and display the attack lines. A brief description of these functions is provided in Table E-9.

The ASWFCO alternate array, shown in Figure E-11, allows the ASWFCO to gather or modify data about the target in order to make better recommendations to the ASWOC and to sonar. Using this array, trial maneuvers can be selected, target depth can be determined, and the target symbol can be repositioned. These functions are summarized in Table E-10.

The ASW data entry array, shown previously in Figure E-4 and described in Table E-4, is used by the ASWFCO in evaluating, detecting, and tracking targets. It also provides ownship weapon and sensor data.

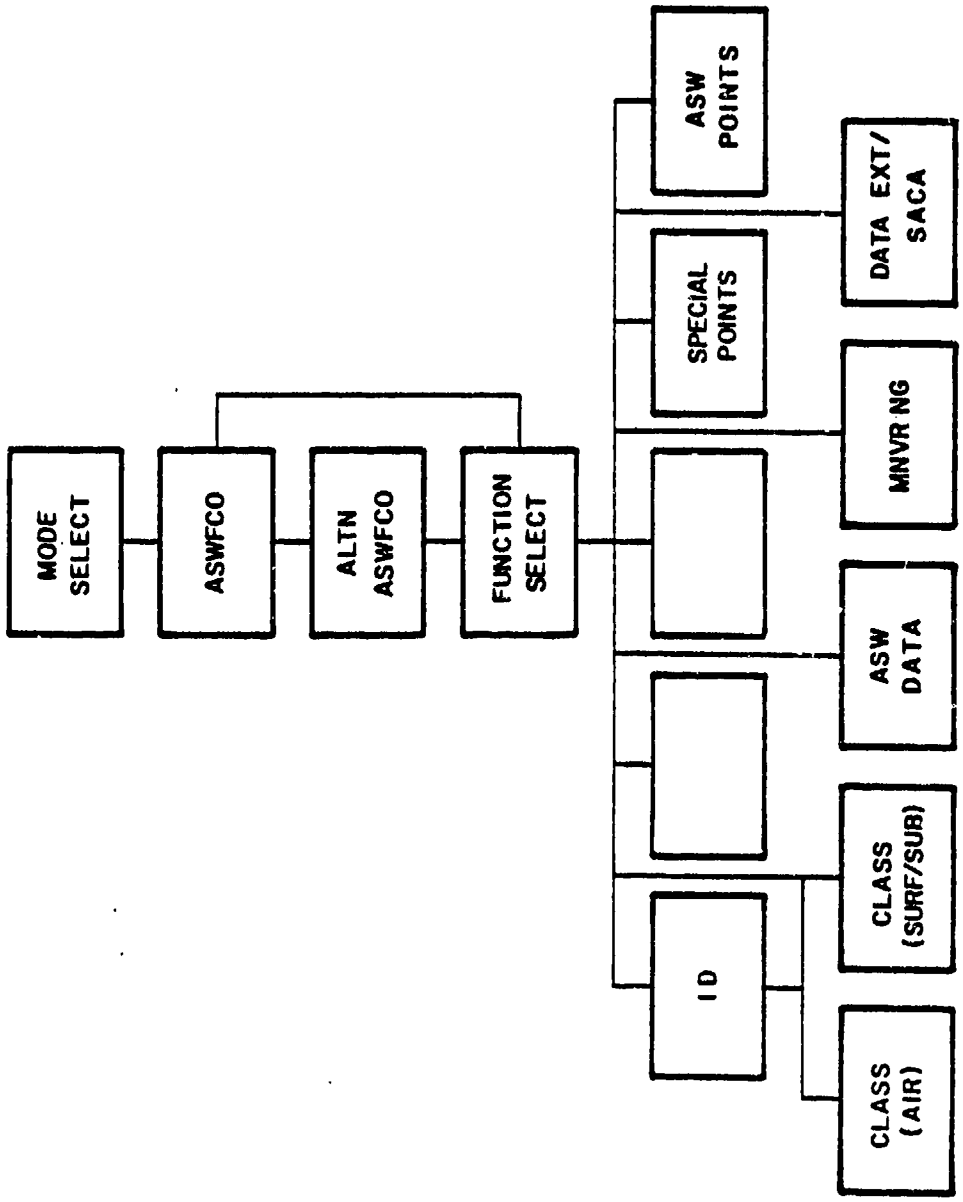
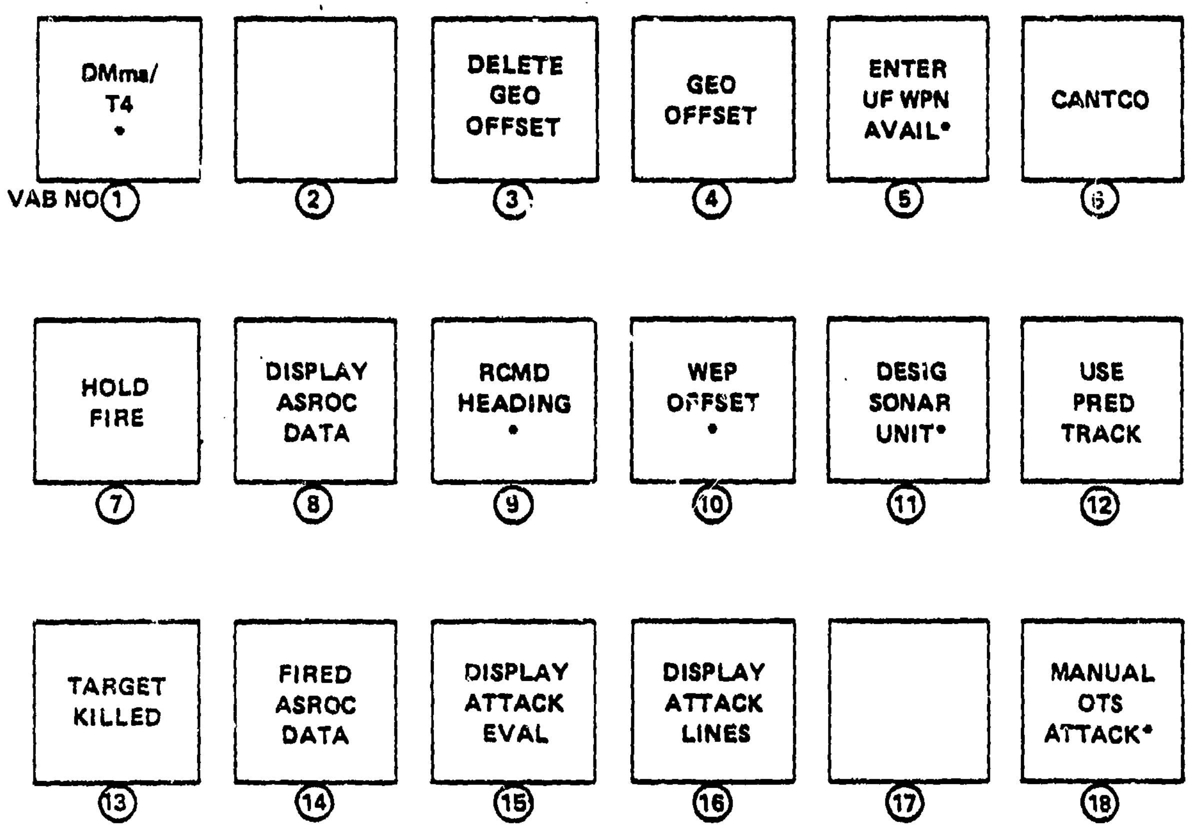


Figure E-9. ASWFCO array tree.



* indicates a DDEU entry accompanies the VAB action.

Figure E-10. ASWFCO primary array.

TABLE E-9. ASWFCO PRIMARY ARRAY FUNCTIONS.

VAB	Label	Function Summary
1	DMma/T4	Indicates one of three specific values of thrust cutoff velocity (DMma) and airframe separation time (T4) to be sent to the MSP for use in a UFCS system operability test.
2	2	Not implemented.
3	DELETE OFFSET	Deletes any offset in effect. If at OSC console FIXED OFFSET must be selected.
4	GEO OFFSET	Causes the PPI symbology at the requesting console to be displayed relative to a specified, fixed geographic point and places the console in an offset mode. If at OSC console FIXED OFFSET must be selected.
5	ENTER UP WPN AVAIL	Enters weapon availability status of the magazines for ASROC torpedo, ASROC depth charge, and OTS torpedoes, and causes the weapon availability status to be displayed at the WCP.
6*	CANTCO	Notifies ASWOC (or SWC if ASWOC is off-line) that ASWFCO cannot comply with an assignment or an engagement order, in response to an assign or engage alert.
7*	HOLD FIRE	Alerts ASWFCO to hold fire on the track in close control.
8*	DISPLAY ASROC DATA	Displays ordered and observed launcher train and elevation.
9*	RCMD HEADING	Forwards a Mk 116 computed or manually entered recommended heading line and alert to the Bridge console when required to unmask the ASROC launcher, bring a target within weapon range, or obtain a launch position for OTS torpedoes.

* Function required in the training scenario.

TABLE E-9. ASWFCO PRIMARY ARRAY FUNCTIONS, CONT.

VAB	Label	Function Summary
10*	WEP OFFSET	Modifies the aimpoint position for ASROC and OTS torpedoes or ASW aircraft weapons to the position specified. Also deletes an existing offset for a specified WEP and causes recomputation of WEP with no offset.
11*	DESIG SONAR UNIT	Orders a sonar unit to search a designated position for a contact.
12*	USE PRED TRACK	Orders the use of, or termination of the use of, predicted track data for the sonar.
13	TARGET KILLED	Notifies SWC, Bridge, ASWOC and other PUs that a target has been destroyed by ownship ASW weapons.
14*	FIRED ASROC DATA	Causes a display of ASROC firing data that was saved at the time of the most recent weapon away signal.
15	DISPLAY ATTACK EVAL	Requests the DRO display of ASROC attack evaluation data at time of intercept or OTS attack evaluation data at the time of torpedo launch.
16*	DISPLAY ATTACK LINES	Causes the PPI display of calculated attack geometry for an ASROC or OTS torpedo engagement when an attack solution exists.
17	DESIG/DELETE ASWFCO	Addresses the symbol in close control to ASWFCO and places an alpha symbol on the track designating the sensor source or deletes the specified symbol and alpha designation from ASWFCO console address list.
18*	MANUAL OTS ATTACK	Initiates or terminates the engagement of a target using an OTS torpedo when the WCP is not available.

* Function required in the training scenario.

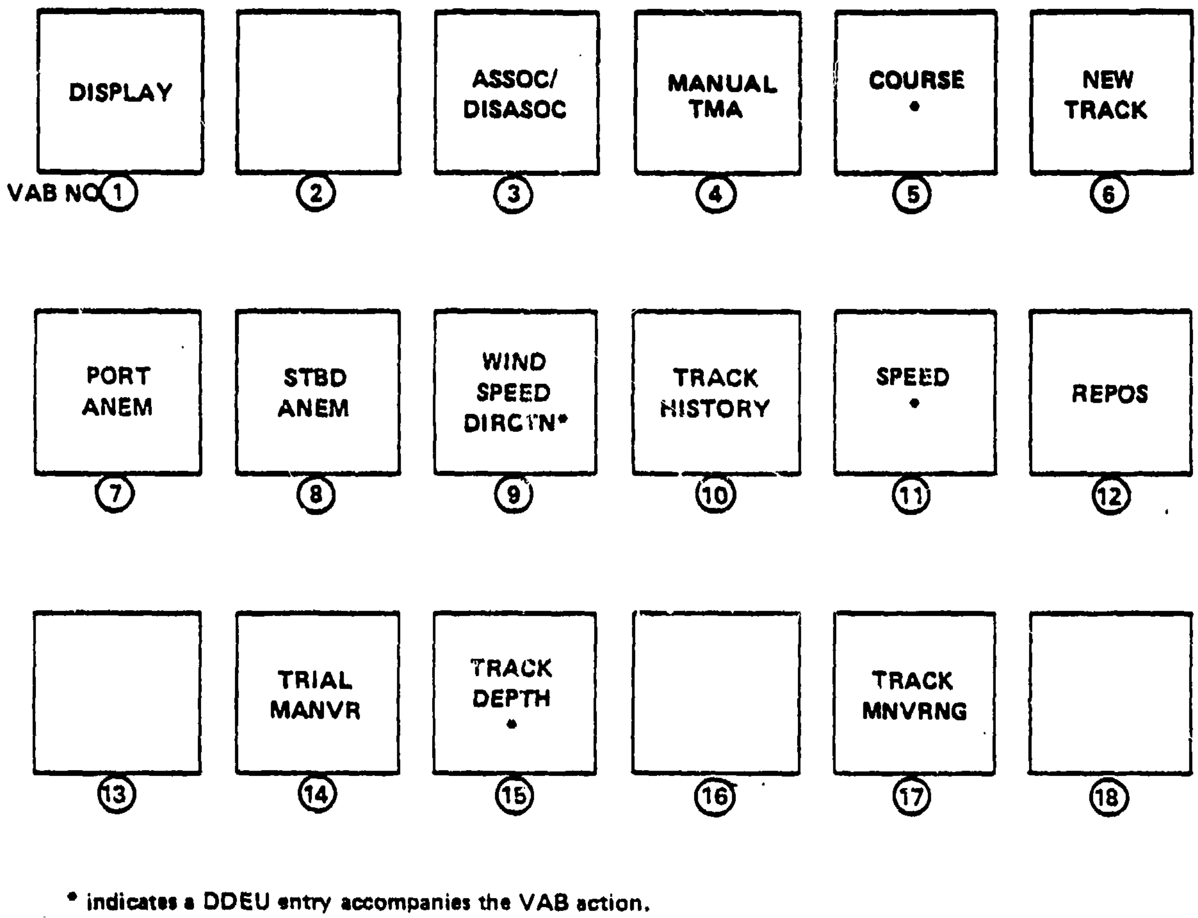


Figure E-11. Alternate ASWFCO array.

TABLE E-10. ASWFCO ALTERNATE ARRAY FUNCTIONS.

VAB	Label	Function Summary
1	DISPLAY	Orders the display of data specified by succeeding VAB actions of WIND SPEED DIRECTN, PORT ANEM, or STBD ANEM VAB.
2	2	Not implemented.
3*	ASSOC/DISASSOC	Associates or disassociates two specified OSS tracks.
4	MANUAL TMA	Initiates manual TMA override for an OSS track or terminates manual TMA override for an OSS track or PK track.
5*	COURSE	Enters a manual value for course on the specified UFCS-reported (OSS or Mk 116 manual subsurface) track or ownship when specified.
6*	NEW TRACK	Manually enters a Mk 116 manual subsurface track at the specified coordinates.
7	PORT ANEM	Enables port anemometer inputs for system use, provides display of current wind data from the port anemometer, and disables inputs from the starboard anemometer. When this VAB action follows a DISPLAY VAB action, wind data from port anemometer inputs is displayed in the Wind Data DRO.
8	STBD ANEM	Same as described above for PORT ANEM, except applied to starboard anemometer.
9	WIND SPEED DIRCTN	Manually enters and displays a value for wind speed and direction or when this VAB action follows a DISPLAY VAB action, causes the display of the Wind Data DRO containing the current wind speed and direction in use by the system.
10*	TRACK HISTORY	Initiates or deletes the display of track history points for specified OSS tracks (maximum of 2) and ownship, or just ownship.

* Function required in the training scenario.

TABLE E-10. ASWFCO ALTERNATE ARRAY FUNCTIONS, CONT.

VAB	Label	Function Summary
11*	SPEED	Enters a manual value for speed on the specified UFCS-reported (OSS or Mk 116 manual subsurface) track or ownship.
12*	REPOS	Repositions the specified UFCS-reported (OSS or Mk 116 manual subsurface) track to the position of the ball tab.
13	13	Not implemented.
14*	TRIAL MANVR	Requests the calculation and display of a collision intercept between a track and another track, special point, or designated location.
15*	TRACK DEPTH	Enters a manual depth or uses the doctrine value for depth on the specified UFCS-reported (OSS or Mk 116 manual subsurface) track.
16	16	Not implemented.
17*	TRACK MNVRNG	Notifies the sonar supervisor via the Sonar Remote DRO that an apparent track maneuver has been observed by the ASWFCO.
18	18	Not implemented.

* Function required in the training scenario.

WEAPONS CONTROL PANEL

In addition to NTDS console functions, the ASWFCO also makes use of the Weapons Control Panel (WCP). This is a sophisticated system that gives the ASWFCO control over the weapons system, provides up-to-date information about the status of the weapon system and ship's sensors, and also provides computer recommendations for heading and firing solutions. Figure E-12 shows the WCP. The buttons and indicators on the panel have been grouped visually by means of dashed lines into functional units for the sake of discussion. The shaded buttons and indicators in this and subsequent figures are not needed in the training scenario.

UPPER CONTROL PANEL CONTROLS AND INDICATORS. Figure E-13 shows the upper control panel controls and indicators in more detail. The only controls needed in this portion of the WCP are the power and intensity controls. Illumination of these buttons is also shown.

SYSTEM MODE SELECTION CONTROLS AND INDICATORS. Figure E-14 shows the system mode selection controls and indicators. The controls are not needed in the training scenario, but the normal illumination of the indicators does convey information and is shown.

SYSTEM STATUS INDICATORS. This two-part indicator is illustrated in Figure E-15. Table E-11 shows the subset of the displays needed in the training scenario.

SYSTEM INTERLOCK STATUS INDICATORS. This six-part indicator is illustrated in Figure E-16. Table E-12 describes the subset of displays needed in the training scenario.

FIRE SWITCH AND FIRING SEQUENCE INDICATORS. The fire switch and firing sequence indicators are illustrated in Figure E-17. The elements are described in Table E-13.

WEAPON INVENTORY ASSIGNMENT AND TRIAL SOLUTION CONTROLS AND INDICATORS. These controls and indicators are illustrated in Figure E-18. The switches cause the displays to indicate what is in each cell or tube. The details are given in Table E-14.

TMA SOURCE, SENSOR STATUS, AND SYSTEM CLEAR CONTROLS AND INDICATORS. These controls and indicators are illustrated in Figure E-19. Their functions are described in Table E-15.

CELL STATUS AND SELECTION CONTROLS AND INDICATORS. The cell status controls are shown in Figure E-20. Their function is described in Table E-16. In the training scenario, only one cell is needed. When the target is within a certain range and the computer recommends an ASROC, cell 1 should have a yellow bar displayed. When it is selected, the green flood should be displayed. These indicators are off if a Mk 46 OTS torpedo is selected.

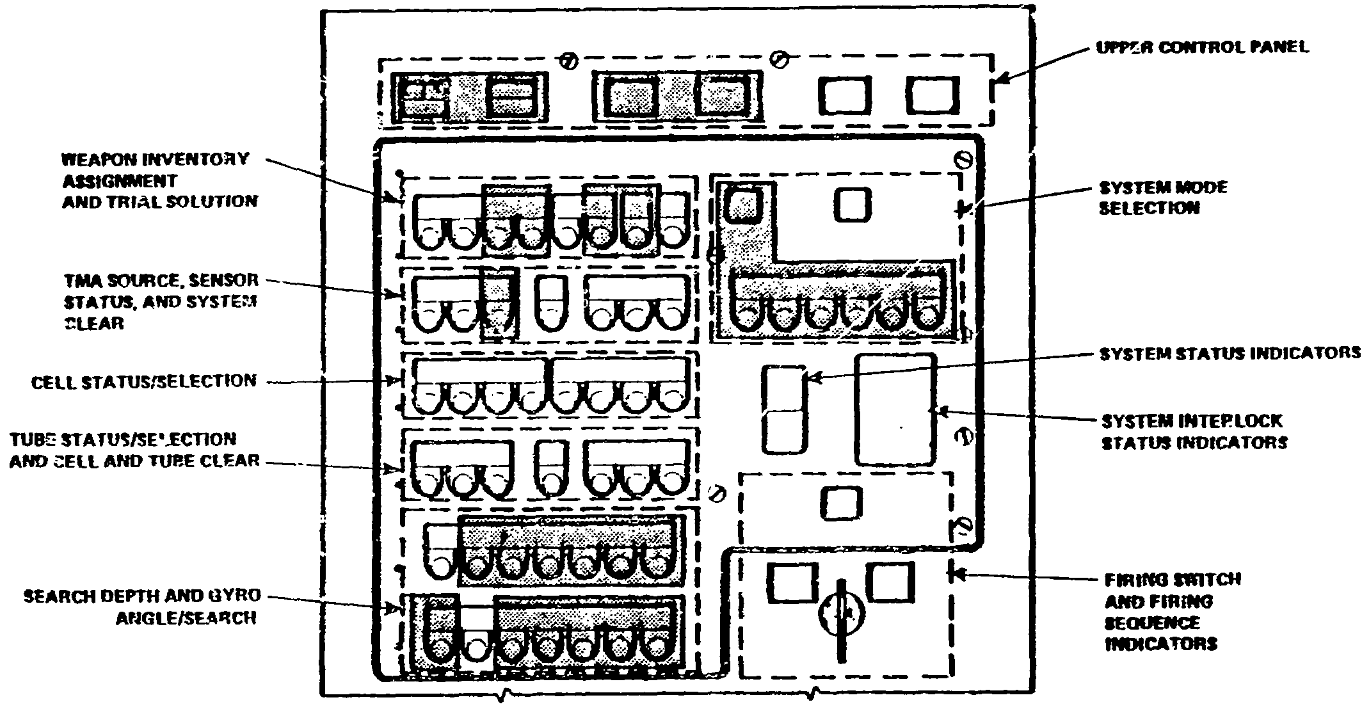


Figure E-12. Weapons Control Panel

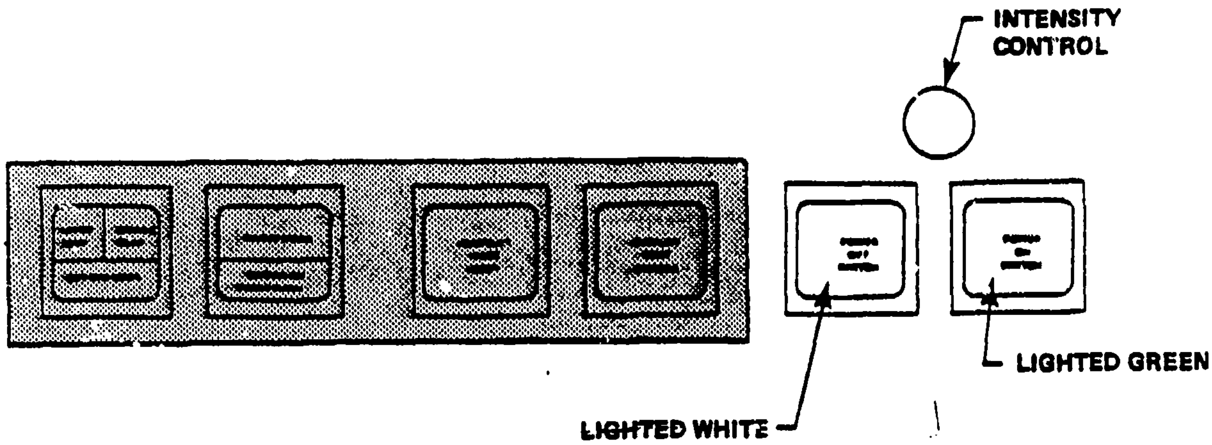


Figure E-13. Upper Control Panel controls and indicators.

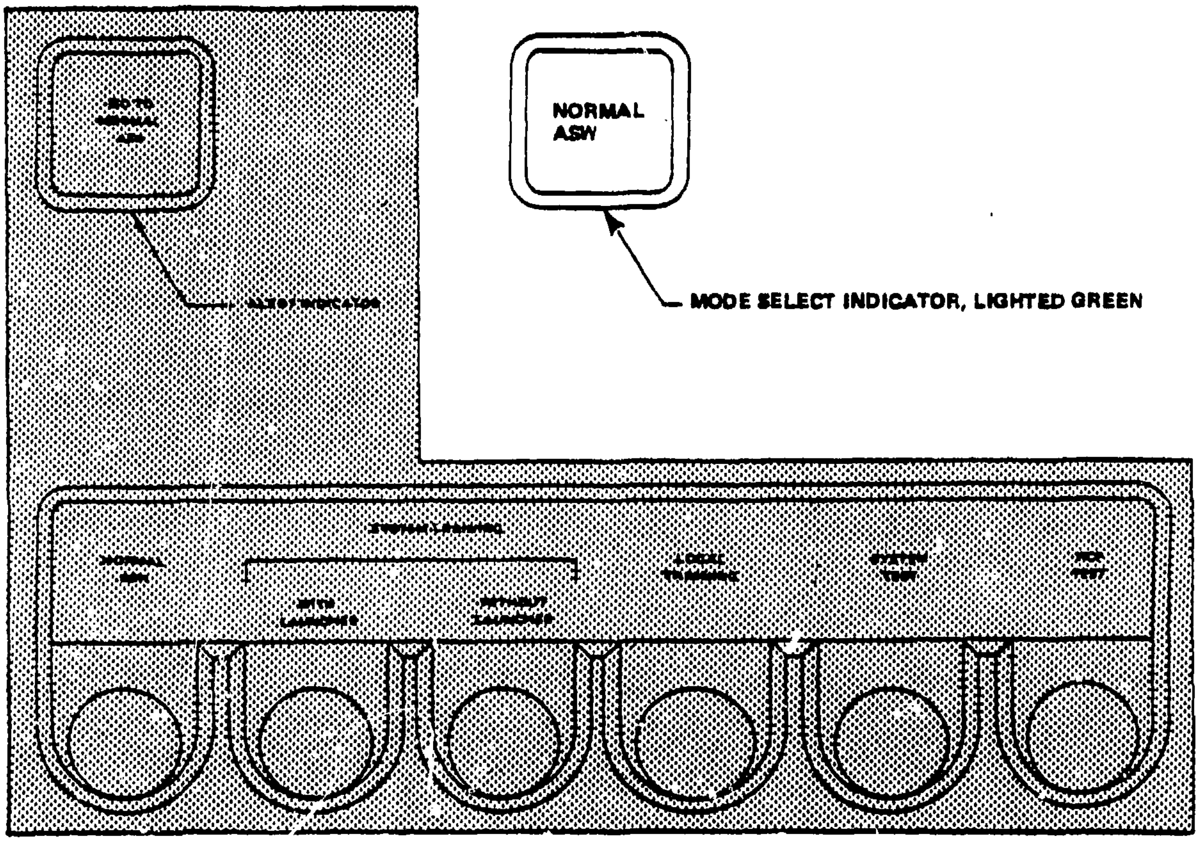


Figure E-14. System Mode Selection controls and indicators.

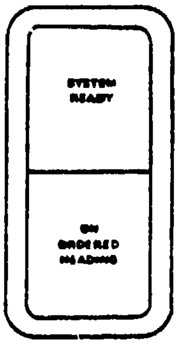


Figure E-15. System Status indicators.

TABLE E-11. SYSTEM STATUS INDICATOR DISPLAYS.

Indicator	Display/Color	Meaning
Top	Approved Torpedo Not Selected	Displayed when WCP status input indicates torpedo approved interlock is satisfied and the Permission To Fire interlock is not.
	Approved Depth Charge Not Selected	Displayed when WCP status input indicates depth charge approved interlock is satisfied and the Permission To Fire interlock is not.
	Bulkhead-Mounted Control Box (BMCB) in Local/Red flood	Displayed when TSP is available and torpedo launching system is not in Remote.
	System Ready/ Green flood	Displayed when no fault or failure legend is illuminated in either the top or bottom System Status Indicator.
	Red flood	Displayed as shown above, or if no alphanumeric legend is ordered and a red flood is displayed on the bottom System Status indicator.
Bottom	Select Torpedo Not Approved	Displayed when WCP status indicates the Torpedo Selected interlock in the WCP is actuated and Permission To Fire interlock is not.

TABLE E-11. SYSTEM STATUS INDICATOR DISPLAYS, CONT.

Indi-cator	Display/Color	Meaning
	Select DC Not Approved	Displayed when WCP status inputs indicate the Depth Charge Selected interlock in the WCP is actuated and the Permission To Fire interlock is not.
Bottom	Red flood	Displayed when no legend is ordered and Red flood is displayed on top System Status indicator or in conjunction with Fault, Mode Error, of DASCO Error indicators if ICSS Error is not displayed.
	Green flood	Displayed in conjunction with Ordered Heading Matched, or if no legend is ordered and Green flood is displayed on top System Status indicator.

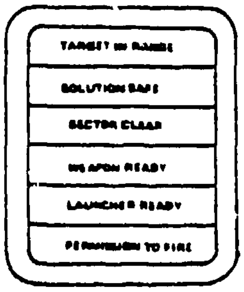


Figure E-16. System Interlock Status Indicators.

TABLE E-12. DESCRIPTION OF SYSTEM INTERLOCK STATUS INDICATORS.

Indicator	Color	Description
TARGET IN RANGE	Off	Not used.
	Green	When an ASROC torpedo, ASROC depth charge, or OTS torpedo is assigned or an ASROC or OTS torpedo is recommended with no weapon assigned and the calculated WEP is within the effective range of the specified weapon.
	Red	When off or green state is not applicable. There is not necessarily an opening of the firing circuit when this indicator is red, but all other interlocks being satisfied, a weapon launched under these circumstances has a very low kill probability.

TABLE E-12. DESCRIPTION OF SYSTEM INTERLOCK STATUS INDICATORS, CONT.

Indicator	Color	Description
SOLUTION SAFE	Off	Not used.
	Green	When a TMA source is selected and an OTS torpedo is assigned, or an ASROC torpedo or ASROC depth charge is assigned and computed WEP range is greater than the specified minimum. (The computer controlled interlock in the WCP will be ordered actuated in the Normal ASW and Training With Launcher modes when an ASROC weapon is assigned and the Solution Safe indicator is green.)
	Red	When off or green is not applicable.
SECTOR CLEAR	Off	Not used.
	Green	OTS torpedo is assigned and the Sector Clear interlock on the TSP is satisfied; or ASROC torpedo or ASROC depth charge is assigned or recommended and a cell is not selected and the computed value of launcher train is within the stored clear firing arc; or ASROC torpedo or ASROC depth charge is assigned and a cell selected and the Launcher Sector Clear interlock is satisfied.
	Red	When off or green is not applicable.
WEAPON READY	Off	Not used.
	Green Flashing	When an ASROC torpedo, ASROC depth charge, or OTS torpedo is assigned and the Weapon Ready interlock in the MSP or TSP is satisfied.
LAUNCHER READY	Green	Launcher ready indicator.
PERMISSION TO FIRE	Off	Not used.
	Green	ASROC: When an ASROC 46 or ASROC DC is assigned, the status input from the Weapon Status Approval Panel indicates that the appropriate weapon is approved, the Permission to Fire signal is received from the WCP, and the Weapon Select switch is in the Missile position.

TABLE E-12. DESCRIPTION OF SYSTEM INTERLOCK STATUS INDICATORS, CONT.

Indicator	Color	Description
PERMISSION TO FIRE, cont.	Green, cont.	OTS: When an OTS is assigned at the WCP, the Permission to Fire signal is received from the WCP, and the Weapon Select switch is in the Mk 32 TT position.
	Red	When off or green is not applicable.

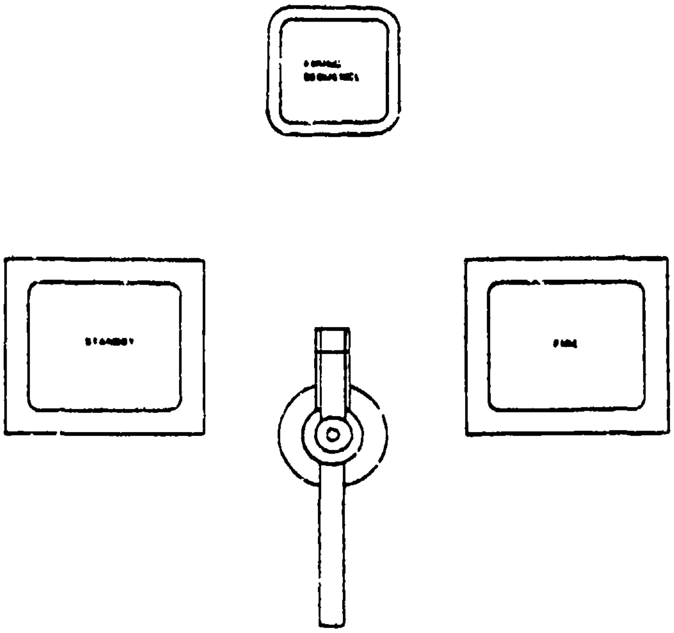


Figure E-17. Fire switch and firing sequence indicators.

TABLE E-13. FIRE SWITCH AND FIRING SEQUENCE INDICATOR FUNCTIONS.

Switch/ Indicator	Color/ Display	Description
Firing Switch	N/A	The firing switch must [illegible] pushed in, then turned. It must be held on [illegible] it will automatically return to the center position. It must be turned to Standby before Fire.
Standby	Green	Illuminated when the Firing Switch is turned to Standby.
Fire	Green	Illuminated when the Firing Switch is turned to Fire.
Firing Sequence	FIRING SEQUENCE	Displayed when a firing sequence has not been initiated or after a firing sequence when the status is cleared by a change in the Cell/Tube select order.
	STANDBY	Displayed when WCP status input indicates that Standby has been ordered and the Ready To Fire condition does not exist.
	READY TO FIRE/ Green	Displayed when Ready To Fire condition exists (3 seconds after Standby for OTS or MSP input) and Fire order has not been issued.
	FIRE ORD-ERED/Red	Displayed when Fire has been ordered and System Misfire has not been present for 1 second, or has been superseded.
	WEAPON AWAY/ Green	Displayed subsequent to weapon launch. This condition will cause the inventory for the selected cell/tube to be changed to empty immediately.

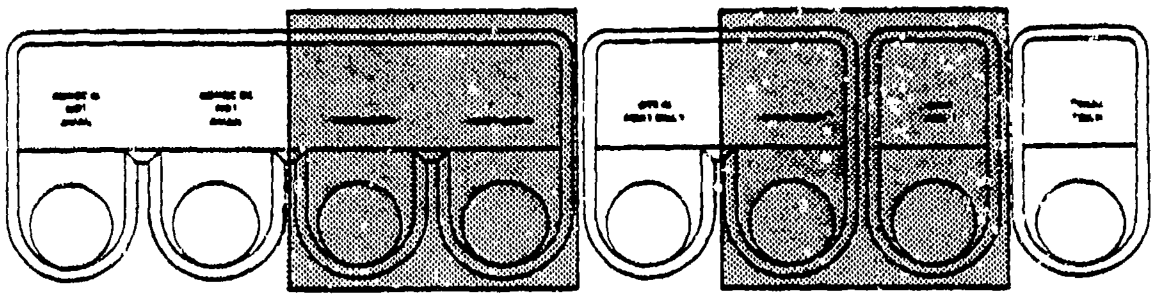


Figure E-18. Weapon Inventory Assignment and Trial Solution controls and indicators.

TABLE E-14. DESCRIPTION OF THE WEAPON INVENTORY ASSIGNMENT AND TRIAL SOLUTION CONTROLS AND INDICATORS.

Display/ Control	Description
ASROC DC LAUNCHER AND MAGAZINE	During Trial Solution, the yellow bar displayed when an ASROC is recommended by the computer and the switch is not depressed; green flood when depressed.
OTS DC MAGAZINE	(Port and starboard) Green flood when depressed.
TRIAL SOLUTION	Works in conjunction with the REQUEST DIR switch on the TMA Source Sensor Status bank of switches. When depressed, the REQ DIR acts as a hold trial solution switch. Green flood when depressed.

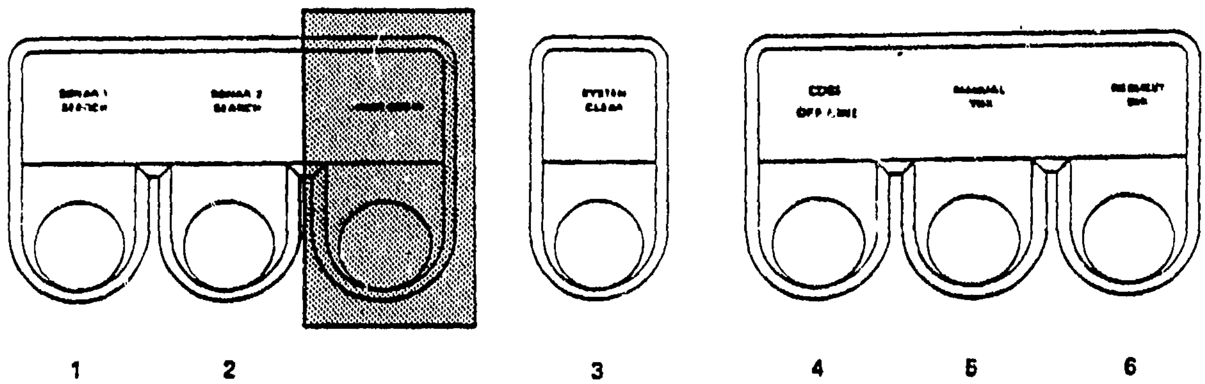


Figure E-19. TMA Source, Sensor Status, and System Clear controls and indicators.

TABLE E-15. FUNCTION OF TMA SOURCE, SENSOR STATUS, AND SYSTEM CLEAR CONTROLS AND INDICATORS.

Number	Display/Color	Description
1	SONAR 1 SEARCH	Displayed when Sonar Channel 1 is on-line, not in contact, and no position kept track originated from Channel 1 input is in Track Stores; flashed for the first 3 minutes after the sonar operator switches from contact to search.
	SONAR 1 TMA GOOD	Displayed when Sonar Channel 1 is in contact, the quality of the automatic TMA solution is good, and the predicted track is not in use.
	PREDICTED TRACK GOOD	Displayed when Sonar Channel 1 is in contact, the quality of the automatic TMA solution is good, and the predicted track is in use.
	Green flood	Displayed when SONAR 1 select switch is depressed and selection is legal.
2	SONAR 2 SEARCH	Displayed when Sonar Channel 2 is on-line, not in contact, and no position kept track originated from Channel 2 input is in Track Stores; flashed for the first 3 minutes after the sonar operator switches from contact to search.

TABLE E-15. FUNCTION OF TMA SOURCE, SENSOR STATUS, AND SYSTEM CLEAR CONTROLS AND INDICATORS, CONT.

Number	Display/Color	Description
2, cont.	SONAR 2 TMA GOOD	Displayed when Sonar Channel 2 is in contact, the quality of the automatic TMA solution is good, and predicted track is not in use.
	PREDICTED TRACK GOOD	Displayed when Sonar Channel 2 is in contact, the quality of the automatic TMA solution is good, and predicted track is in use.
	Green flood	Displayed when SONAR 2 select switch is depressed and selection is legal.
3	SYSTEM CLEAR	When depressed, all WCP orders to the operational program are canceled except System Mode order and Trial Solution Hold (if implemented). A Trial Solution Hold order is canceled when SYSTEM CLEAR is depressed a second time. Break engage processing is performed for the target identified by the selected data source. Associated attack geometry is deleted from the UYA-4 console. Computations and hardware output relating to the selected weapon system are stopped.
4	CDSS/Green flood	The CDSS select switch orders utilization of track input data from the CDSS or NTDS for generation of an attack solution. It places a CDSS surface or subsurface track in close control at the ASWFCO console. The green flood is displayed when the switch is depressed and the solution is a legal action.
	CDSS RADAR TARGET	Displayed when the source of an NTDS-reported subsurface track is identified as a radar.
	CDSS REMOTE TRACK	Displayed when an NTDS-reported subsurface track is not identified as a radar track (e.g., remote track, CDSS position kept track, etc.).
5	MANUAL TRK/Green flood	This control is used to place a manual subsurface track in close control at the ASWFCO console. Green flood is displayed when this switch is selected legally.

TABLE E-15. FUNCTION OF TMA SOURCE, SENSOR STATUS, AND SYSTEM CLEAR CONTROLS AND INDICATORS, CONT.

Number	Display/Color	Description
5, cont.	MANUAL TRACK ENTERED	Displayed when a manual subsurface track is under assignment or engagement from the WCP or when a manual subsurface track symbol is in close control and the track is not under engagement from the WCP.
6	REQUEST DIR	Displayed when Trial Solution Hold is not enabled and Request Director Select switch is not depressed, or after depressing, a response to request has not been received from CDSS. The switch causes a message to be sent to NTDS giving coordinates of the ASROC WEP and a TRACK WEP REQ alert is sent to SWC.
	Yellow bar	Displayed when REQUEST DIR select switch has not been depressed, an ASROC torpedo or ASROC depth charge is assigned, and all Interlock Status indicators are green.
	Red flood	Illegal REQUEST DIR.
6	Green bar	Displayed when REQUEST DIR has been depressed and an assigned message is not received from CDSS.
	DIRECTOR ASSIGNED/ Green flood	Displayed when REQUEST DIR has been depressed and an assigned message is received from CDSS.
	TRIAL SOLUTION HOLD	This legend replaces REQUEST DIR legend when TRIAL SOLUTION is depressed. It is displayed when trial solution is ordered at WCP until solution hold is cleared, or if hold is not ordered, until trial solution is cleared.
	Green flood	Displayed when Trial Solution Hold select switch is depressed until Hold condition is cleared.

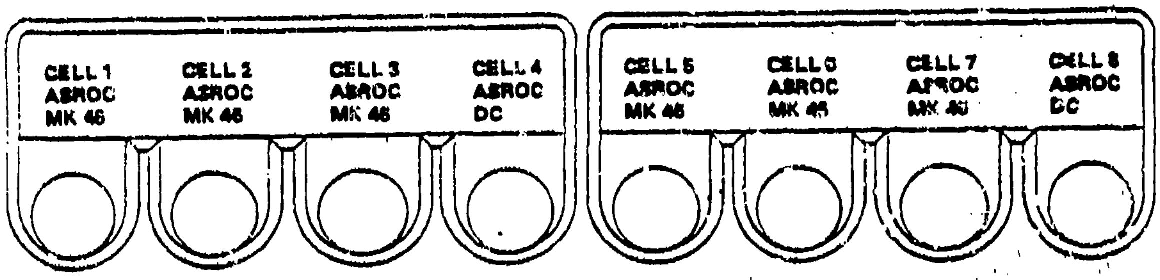


Figure E-20. Cell Status and Selection Controls and Indicators.

TABLE E-16. FUNCTION OF CELL STATUS AND SELECTION CONTROLS AND INDICATORS.

Display/ Color	Description
CELL # ASROC Mk 46	Displayed when the inventory for cell # is an ASROC Mk 45 torpedo. In the training scenario, this will include cells 1,2,3,5,6,7, as shown.
CELL # ASROC DC	Displayed when the inventory for cell # is an ASROC depth charge. In the training scenario, this will include cells 4 and 8, as shown.
Green flood*	Displayed when CELL # select switch is depressed, inventory for cell matches the assigned weapon, and Launcher Selector switches have responded correctly.
Yellow bar*	Displayed when CELL # select switch has not been depressed and cell is recommended or cell was selected prior to TRIAL SOLN HOLD selected.

*Note: These are off if a Mk 46 OTS torpedo is selected.

TUBE STATUS AND SELECTION, CELL AND TUBE CLEAR CONTROLS AND INDICATORS. Tube status controls are illustrated in Figure E-21. They are described in Table E-17. These indicators are off if an ASROC has been selected. In the training scenario, only one port and one starboard tube is needed. When an OTS torpedo is selected at the weapon assignment, a yellow bar should appear in tube 1 and 2.

SEARCH DEPTH AND GYRO ANGLE/SEARCH CONTROLS AND INDICATORS. These controls and indicators are shown in Figure E-22 and are described in Table E-18. Since in the training scenario, the ASROC depth charge must not be selected, and since the depths are predetermined, a depth should be selected and the yellow bar should be used to recommend it. In this way, only the unshaded switch in the upper bank needs to be functional. A similar approach can be taken in the lower bank, and again only the one unshaded switch would need to be functional.

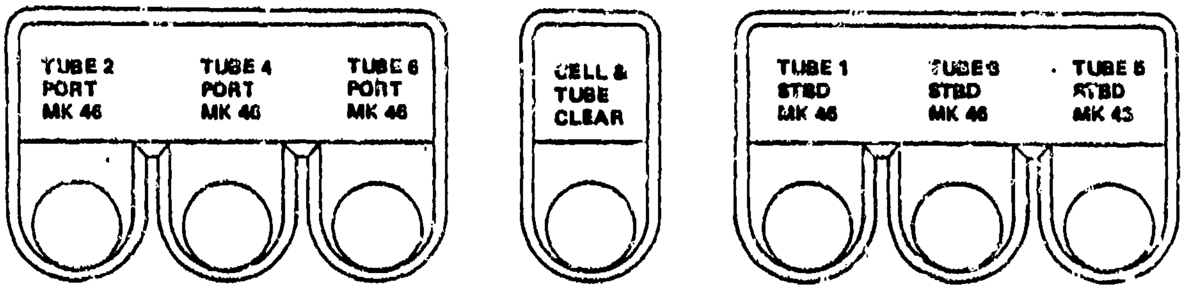


Figure E-21. Tube Status/Selection, Cell and Tube Clear controls and indicators.

TABLE E-17. DESCRIPTION OF TUBE STATUS/SELECTION, CELL AND TUBE CLEAR CONTROLS AND INDICATORS.

Display/ Color	Description
TUBE # PORT/ STARBOARD MK 46	Displayed when the inventory for the tube is a MK 46 torpedo.
Green flood*	Displayed when TUBE # select switch is depressed, inventory for the tube matches the assigned weapon, and the TSP Tube select switch has responded correctly.
Yellow bar*	Displayed when TUBE # select switch has not been depressed and the tube is recommended, or tube was selected prior to TRIAL SOLN HOLD selected.
CELL AND TUBE CLEAR	Depressing this switch cancels any previously actuated CELL or TUBE select switches or Torpedo setting switches and their resulting actions and indications.

*Note: These are off if an ASROC is selected

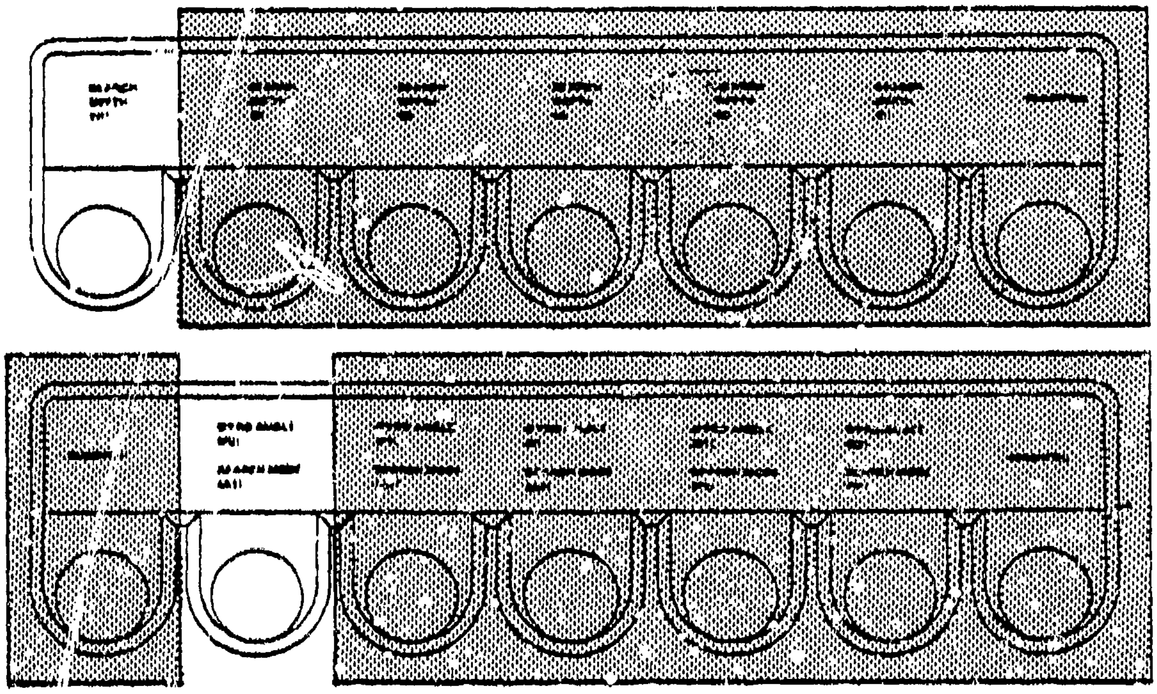


Figure E-22. Search Depth and Gyro Angle/Search Controls and Indicators.

TABLE E-18. DESCRIPTION OF SEARCH DEPTH AND GYRO ANGLE/SEARCH CONTROLS AND INDICATORS USED IN THE SCENARIO.

Display	Color	Description
SEARCH DEPTH		Displayed at all times during Normal ASW mode unless an ASROC depth charge is assigned.
	Green flood	Displayed when a SEARCH DEPTH # select switch is depressed and the torpedo mechanism is set at Search Depth #. This is equivalent to a search depth sync indication.
	Yellow bar	Displayed when a SEARCH DEPTH # select switch has not been depressed and Search Depth # is recommended, or SEARCH DEPTH # was selected prior to the TRIAL SOLN HOLD selected.
GYRO ANGLE #		Displayed when no weapon is assigned or OTS Mk 46 is assigned and a combination of Gyro Angle # and Tube Select does not cause torpedo track to cross ownship bow.
	Green flood	Displayed when a GYRO ANGLE #/SEARCH MODE # select switch is depressed and the torpedo mechanism is set at Gyro Angle #/Search Mode #. This is equivalent to a Gyro Angle/Search Mode sync indication.
	Yellow bar	Displayed when a GYRO ANGLE #/SEARCH MODE select switch has not been depressed and Gyro Angle #/Search Mode is recommended, or GYRO 74 ANGLE #/SEARCH MODE # was selected prior to TRIAL SOLN HOLD selected.
SEARCH MODE #		Displayed when an ASROC torpedo is assigned.

APPENDIX F

COMMUNICATIONS CIRCUITS

The members of the CIC team use a variety of circuits to receive and transmit information. The internal and external circuits which will be needed to support the training scenario are described in Tables F-1 and F-2 respectively.

TABLE F-1. INTERNAL COMMUNICATIONS CIRCUITS.

Circuit	Type	Stations	Type of Information
61JS	Sound powered	ASWFCO, ASWOC, Sonar, North Plotter, Bridge	Flow of contact information; Shift of control
29MC	Multi-channel unit	Sonar	One way sonar contact announcing
1JS	Sound powered	ASWOC*, Surface Sup., Bridge	Ships control information (e.g. course, speed changes)
21JS	Sound powered	Radar oper., South plotter, ASAC*, ASWOC*	Internal CIC information (e.g. range, bearing to assist ship after contacts)
JC	Sound powered	ASWFCO, Weapons	Weapons status tube conditions
Interphone	NTDS intercom circuit	ASWOC*, ASWFCO*, ASAC*, All consoles*	General purpose communications circuit for orders and information
8JP	Sound powered	ASWFCO, Launcher	Directions to the launch captain

*Note: At the stations marked with an asterisk, a light alerts the station that another station wishes to communicate over the circuit. It is necessary to switch manually to the circuit to communicate, then switch back to the normally manned circuit.

TABLE F-2. EXTERNAL COMMUNICATIONS CIRCUITS.

Circuit	Type	Stations	Type of Information
SAU Reporting	Radio telephone All ships	All ships of the SAU, assist ship, SAU Commander, ASWOC	All contact/datum information; maneuvers, orders for SAU
Submarine Coord.	Radio telephone Command level	SAU Cmdr, OTC	Information about contact; tactics
Air Coord.	Radio telephone and control units	ACU, SAU Cmdr, Helo home plate, OTC	Request for helos, helo state, status, RTB notification
ASW Helo Control	Radio telephone helo control	ASAC Helicopter	Vectors, MAD reports, air control

APPENDIX G

AUTOMATED SPEECH TECHNOLOGY REQUIREMENTS

The Team Training system will require the use of both the automated speech recognition and automated speech generation technologies. In this appendix, the vocabulary used during the scenario by each member of the CIC team and by supporting team members is defined in its most general form. Although it is not within the scope of this effort to do detailed trade-off analyses of the presently available hardware devices and software techniques which could support training system needs, the vocabulary lists given here will provide the basis for conducting such studies. A concluding section of the appendix provides checklists for evaluating hardware devices.

SPEECH RECOGNITION REQUIREMENTS

The system concept described in this report involves a training system for three members of the CIC t am: the ASWOC, ASWFCO, and ASAC. Thus the system must be capable of recognizing and understanding the vocabulary used by these team members. The distinction between "recognizing" and "understanding" is crucial here. By recognition we mean the ability of a hardware speech recognition device to detect that a particular word or phrase has been spoken. By understanding, we mean the ability of the training system as a whole to respond properly to an input. Only the speech **recognition** requirements are described here. The specification of system responses to these speech inputs, the **understanding** function, was provided in the classified Appendix C.

The phrase lists provided here have been arranged to show complete utterances rather than the particles which would actually be recognized by the hardware recognition device. The machine-dependent task of defining those particles is beyond the scope of this effort.

A feature of the training system concept is its capability to stand in for missing team members by providing competent team member models. Thus the vocabulary lists given below for the ASWOC, ASWFCO, and ASAC are lists of words and phrases which the system must both be able to recognize and to generate.

Table G-1 shows the special symbols used to define the vocabulary. Table G-2 shows the words used by all team members on all circuits. Table G-3 provides a list of the phrases used by the ASWOC, arranged by circuit. This arrangement by circuit is important for two reasons: Obviously the speech generation system needs to output the verbalizations of the team member models over the appropriate circuit. More importantly, the arrangement provides a powerful method of partitioning the extensive vocabulary for efficient speech recognition. Tables G-4 and G-5 give the phrases used by the ASWFCO and ASAC respectively.

TABLE G-1. MEANING OF SYMBOLS USED IN THE TABLES.

Symbol	Meaning
,	Pause may occur.
{}	Optional word or phrase.
/	Separates mutually exclusive choices within a phrase.
_	Used to remove ambiguity when mutually exclusive choices in a phrase involve more than one word. For example, the entry "TDA/tango_delta_alpha" means that either the abbreviation is used, or the three phonetic alphabet elements.
[]	Variable information of the type specified is to be inserted, as follows: [range] and [interval] are expressed in either yards or miles: [digit] {decimal [digit] {miles}}; [digit] {answer} {miles}; [whole number] hundred/thousand/answer {yards}. [time] is expressed as follows: [digit] [digit]; according to the 24 hour clock. [speed] is expressed in knots: [digit] {knots}; [whole number]/[digit digit] {knots}. [course], [heading] and [bearing] are expressed as 3 digits in the range 001 to 360. (Course can also be given as 000.) [alpha/bravo...] means a word from the phonetic alphabet. [compass point] means north/north north west/north west/...

TABLE G-2. WORDS AND PHRASES USED BY ALL TEAM MEMBERS.

Circuit	Phrase
All	Roger
	Roger out
	Over
	Out
	Aye
	Negative
	Tack
	Standby
	And
	Zero*, one, ..., nine, niner, ten, eleven, ..., ninety
	Alpha, bravo, ..., zulu

*Note: The substitution of "oh" for "zero" is not acceptable Navy phraseology.

TABLE G-3. PHRASES USED BY THE ASWOC.

Circuit	Phrase
SAU Reporting	Interrogative weapons policy.
	Lima 2 on station.
	Lima 2 laying a barrier axis [true compass bearing] king pin [bearing] degrees [range] Delta Charlie/Lima 2.
	Lima 2 {has} MADman [bearing] Delta Charlie/Lima 2 [range].
	Conducting MAD vecs with Lima 2.
	Lima 2 lost contact [bearing] Delta Charlie/Lima 2 [range], tracking [course], indicating/speed [speed].
	Entering TDA/tango_delta_alpha.
	I am hot [bearing] {tack} [range].
	My latest [bearing] {tack} [range].
	Classify as pos/prob/cert sub confidence {level} high/low.
	Execute plan red/black/green/yellow.
	I am brother/sister.
	Coming left/right [course].
	Prep bassett port/starboard.
	Firing bearing [bearing].
	Bassett away bearing [bearing] time [time].
	Bassett splash, water entry point [bearing] {tack} [range].
	Safe time [time].

TABLE G-3. PHRASES USED BY THE ASWOC, CONT.

Circuit	Phrase
61JS	Use datum as search center.
	Entering TDA/tango_delta_alpha.
	{Lima 2} MADman [bearing] {tack} [range].
	Sonar contact [bearing] {tack} [range].
	Classify as pos/prob/cert sub, confidence {level} high/low.
	We are the attacking ship.
	Weapons policy: weapons free pos sub confidence level high or higher.
	Assign MK 116 to the sonar contact bearing [bearing].
	Engage MK 116.
	Prep Bassett port/starboard.
	Complete your firing sequence.
	Shoot.
	Execute to follow turn [alpha/bravo...] desig [alpha/bravo...] {tack} [course].
	When executed the base course will be [course] zigzag plan [alpha/bravo...].
	Execute zigzag plan.
	Plan red/black/green/yellow executed.
	Come left/right to course [course].
	Next course will be [course] at time [time].

TABLE G-3. PHRASES USED BY THE ASWOC, CONT.

Circuit	Phrase
61JS, cont.	Weapons policy: weapons free pos sub confidence level high or higher.
	Entering TDA/tango_delta_alpha.
	Execute to follow turn [alpha/bravo...] desig [alpha/bravo...] {tack} [course].
	When executed the base course will be [course] zigzag plan [alpha/bravo...].
	Execute zigzag plan.
	Come left/right to course [course] {at time [time]}.
	Come left/right steer [course].
	Next course will be [course] at time [time].
	MADman [bearing] {tack} [range].
	Lima 2 lost contact [bearing] {tack} [range].
	Firing bearing [bearing].
	Bassett away [bearing].
	Water entry point [bearing] {tack} [range].

TABLE G-3. PHRASES USED BY THE ASWOC, CONT.

Circuit	Phrase
NTDS Interphone	Lay a barrier with Lima 2 with buoy interval of [interval] axis [true compass bearing] from [bearing] {tack} [range] from datum.
	Weapons policy: weapons free on pos sub confidence level high or higher, Lima 2 weapons free after third MAD contact.
	Weapons free on next MAD contact.
	Sonar contact [bearing] {tack} [range].
	Scram Lima 2 [heading]/[compass point].
	Prep bassett port/starboard.
	Bassett away port/starboard.

TABLE G-4. PHRASES USED BY THE ASWFCO.

Circuit	Phrase
61JS	Search mode ODT PDT.
	The helo has a MAD contact [bearing] {tack} [range].
	Shift your search center to [relative bearing]/datum.
	New search arcs [relative bearing] to [relative bearing].
	Contact tracking [course] indicating/speed [speed].
	Lima 2 lost contact, last known position [bearing] {tack} [range].
	Signal strength strong/weak, signal quality sharp/fuzzy.
	Classify as pos/prob/cert sub confidence {level} high/low.
	That looks like Lima 2's MAD contact tracking [course] indicating/speed [speed].
	MK 116 assigned.
	I have/see the contact tracking [course] indicating/speed [speed].
	I am offsetting [range] ahead/port_bow/starboard_bow of the contact.
	Prepping bassett port/starboard.
	I have a green board one, recommend [ocurse].
	Firing bearing [bearing].
	Request permission to fire.
	Green board two.
	Bassett away firing bearing [bearing].
	Bassett splash, water entry point [bearing] {tack} [range].

TABLE G-4. PHRASES USED BY THE ASWFCO, CONT.

Circuit	Phrase
61JS, cont.	Listen for weapon start up.
	Shot looks good, [range] ahead/port_bow/starboard_bow of contact.

8JP	Match up bearing and elevation and shift to remote.
	Insert P1 plug.

TABLE G-5. PHRASES USED BY THE ASAC.

Circuit	Phrase
NTDS Interphone	Lima 2 on station commencing plant.
	Standby for king pin.
	Mark king pin {[bearing] {tack} [range]}.
	Plant complete axis [true compass bearing].
	MADman MADman [bearing] {tack} [range].
	Conducting MAD vec with Lima 2.
	Lost contact, last known position [bearing] {tack} [range].
	Lima 2 clear [compass point].
ASW Helo Control Net	Lima 2 this is Freddy override.
	Lima 2 lay a road [true compass bearing] from position [bearing] {tack} [range] Delta Charlie/Lima 2, interval [interval], drop on my command.
	Lima 2 vector [heading] for station.
	Lima 2 port/starboard [heading].
	Lima 2 standby to drop.
	Lima 2 drop now...now...now.
	Lima 2 king pin.
	Lima 2 stand by {[range]}.
	Lima 2 execute preview.
	Lima 2 vector [heading] for ID/initial_drop_point.
	Lima 2 execute radar MAD vec.
	Lima 2 port or starboard [1 or 2 digit(s)] to [1 or 2 digit(s)] as needed.

TABLE G-5. PHRASES USED BY THE ASAC, CONT.

Circuit	Phrase
ASW Helo Control Net, cont.	Lima 2 mark on top.
	Lima 2 port/starboard [heading] line_up_on_the_smoke/for_another _pass.
	Lima 2 weapons free classify a pos sub confidence {level} high.
	Lima 2 I am hot [bearing] {tack} [range].
	Lima 2 scram [heading]/[compass point].
	Lima 2 prep bassett port/starboard.
	Lima 2 bassett away port/starboard.

SPEECH GENERATION

Speech generation is often regarded as a much more simple task than speech recognition. In a sense, this is true. However, the extensive speech generation requirements of this training system will make the design of an adequate speech generation system a challenge. First of all, it must provide distinguishable speech output of nine different talkers: the ASWOC, ASWFCO, ASAC, plotter, sonar operator, bridge, SAU commander and helicopter pilot, and instructor. Furthermore, it should be capable of varying the output of certain messages much like a human would. As a simple example, it should sometimes say "Aye" and at other times "Roger." It also must choose the appropriate circuit over which to transmit the appropriate voice message.

The phrases which the ASWOC, ASWFCO, and ASAC use were described in the preceeding section. In the following, Tables G-6 through G-10 list the phrases used by the plotter, sonar operator, bridge, SAU commander and helicopter pilot respectively. In addition, all models should have the capability to speak the words and phrases given in Table G-1.

No speech messages have yet been defined for the instructor model, and so no table of phrases can be provided at this time. Nonetheless, this model should be taken into consideration in the design of the speech generation capability, with provision made for this model to provide set up descriptions and extensive feedback. It is particularly important to take ease of modification into consideration in the design of the instructor model speech generation capability, since one of the purposes of the system is to investigate the efficacy of various forms of feedback.

TABLE G-6. PHRASES USED BY THE PLOTTER.

Circuit	Phrase
61JS	Concur ETA/echo_tango_alpha to TDA/tango_delta_alpha.
	Concur cone of courses.
	Initial course for zigzag [course].
	I hold us entering the TDA/tango_delta_alpha.
	I see/hold the sub tracking [course] indicating/speed [speed].

TABLE G-7. PHRASES USED BY THE SONAR OPERATOR.

Circuit	Phrase
61JS or 29MC	Tracking the contact on [alpha,bravo...] scan [bearing] {tack} [range].
	Sonar contact [bearing] {tack} [range].
	Signal strength strong/weak, signal quality sharp/fuzzy.
	Classify as pos/prob/cert sub confidence {level} high/low.

TABLE G-8. PHRASES USED BY THE BRIDGE.

Circuit	Phrase
61JS	Come left/right to [course].
	Next course will be [course] at time [time].
	Bearing clear.

TABLE G-9. PHRASES USED BY THE SAU COMMANDER.

Circuit	Phrase
SAU Reporting	Plan red/black/green/yellow.
	Cone of courses high speed leg [bearing?] {tack} [speed].
	Low speed leg [bearing] {tack} [speed].
	Sector assignment [bearing] to [bearing] desig [call sign].
	ETA/echo_tango_alpha TDA/tango_delta_alpha [time].
	Execute to follow turn [alpha/bravo] desig [alpha/bravo] [course].
	I am brother/sister.

TABLE G-10. PHRASES USED BY THE HELICOPTER PILOT.

Circuit	Phrase
ASW Helo Control Net	On your command.
	Mike speed [speed] cherubs [digit].
	King pin.
	Spit one maypole.
	Road complete.
	Conducting M2 [compass point] present position.
	MADman MADman MADman.
	No joy this pass.
	[speed] buster.
	I am buster.

EVALUATION OF AUTOMATED SPEECH HARDWARE

Although it is not within the scope of this project to perform trade-off studies to determine the best automated speech hardware for the training system, the questions given in Tables G-11 and G-12 provide a starting point for performing such an evaluation.

TABLE G-11. SPEECH RECOGNITION DEVICE CHECKLIST.

Does the device recognize isolated words or phrases, or continuous speech?
What stylization constraints are imposed?
How long an utterance can be accepted?
How is recognition accuracy affected by having both relatively short and relatively long phrases in the vocabulary?
What is the maximum vocabulary size the device can recognize?
Does recognition accuracy vary between male and female talkers?
What is the recognition accuracy **for the vocabulary needed for my application**?
How is recognition accuracy related to vocabulary size?
How fast is speech recognition?
How is speech recognition rate related to vocabulary size?
Can the recognition unit be directed to restrict its search to a few items in the vocabulary? (Partitioning the vocabulary can improve recognition.)
Does the unit supply a measure of confidence in the recognition result?
Does it provide a second and even third choice when it is not sure what was spoken?
Can the threshold for supplying a second choice be adjusted?
Can the threshold for whether or not recognition has occurred be adjusted? (In some applications, any clue to what was spoken is helpful, thus one threshold is needed. In other applications, it is necessary to minimize the possibility of a recognition error, hence a different threshold is appropriate.)
What is the effect of background noise on the system?
Can it recognize speech over the telephone?
Does the unit supply an indication of voice level with the recognition? (Poor microphone placement, common with the naive user, can lead to poor recognition. With an indication of voice level, the system has a clue to the reason for poor recognition and can provide helpful feedback. At present, this feature is not known to be commercially available, and has had to be implemented as a special purpose device for our own applications.)
Is the device speaker dependent?
If so, how many times does each word have to be repeated in order to configure the system to recognize an individual talker?
How is recognition accuracy related to number of repetitions?
Can the data for an individual talker be saved on an easily accessible external medium, or does the system have to be reconfigured each time it is used?
Can the configuration process be tailored to the needs of the individual application?
- Can a few items be trained at a time?
- Can the order of presentation be varied or does the talker have to repeat each item a number of times in succession?
- Can a single speech pattern be updated easily?

TABLE G-11. SPEECH RECOGNITION DEVICE CHECKLIST, CONT.

How much host computer memory is needed for:
- Speech system configuration and update procedures?
- Speech recognition procedures?
- Speech data storage (raw input data and voice patterns)?

How does the host computer communicate with the device?
- What is the I/O processing burden?
- What type of interface is provided?
- Is the data transfer rate sufficient?
  - How long does it take to transfer speech patterns?
  - How long does it take to transfer recognition information?

How sensitive to damage are the components which the user carries or wears? (Some noise canceling microphones can be irreparably damaged by dropping them from even a short distance. Users <u>will</u> drop them and also accidentally tug on the cords, etc.)

TABLE G-12. SPEECH GENERATION SYSTEM CHECKLIST.

How much time is required to create the required vocabulary? (Even "text to speech" devices require some hand smoothing of the phrases to achieve good inflection, etc.)

How easy is it to change the vocabulary? (Some devices require encoding by the manufacturer.)

To what extent can individually stored words or phrases be put together dynamically to produce real-time output in response to a changing situation? (The resulting speech is usually <u>very</u> choppy.)

How many different voices can be simulated?

Is speech rate under computer control?

How fast can the device speak?

Is pitch under computer control?

Does the device notify the computer that speech output is complete?

Does the device require a data storage area to be provided by the host computer?

If so, approximately how many words of data storage are required per word or per second of speech?

What I/O burden does the system place on the computer?

APPENDIX H

SOFTWARE DESIGN CONSIDERATIONS

This section addresses itself to the software design issues which will significantly influence the development and evolution of the team training demonstration system. The principal design issues which will be discussed below are simulation, speech, and software architecture.

SIMULATION METHODS

According to the American Heritage Dictionary, the word simulate means "to have or take on the appearance, form, or sound of; to imitate." This definition is just possibly broad enough to cover the realm of things which simulation software attempts. Historically, simulation software was first created to model deterministic physical processes and engineering structures; later probabilistic methods (e.g., Monte Carlo schemes) were created to model situations too complex for the earlier deterministic approaches. In the last decade or so, simulation has developed into a much broader notion, wherein the something which is imitated may include complex human behavior and sophisticated decision making.

It is pretty obvious that simulation methods which are appropriate to model a physical process may well be inadequate to represent complex human behavior. Simulations of the consistency of mud for oil drilling, of high performance aircraft for durability testing, of wheat price fluctuations for economic forecasting, and of human performance in high pressure decision making environments may be qualitatively quite different. In the matter of simulation languages, for example: FORTRAN is a very convenient vehicle for the simulation of physical processes. It has some undesirable features for the representation of complex mathematics, but from a practical standpoint it is really quite functional (much more so than its many vocal critics would admit). On the other hand, representations of human behavior - or most anything else that is not number (or data) intensive tends to be rather awkward in FORTRAN. Other languages and systems have stepped in to fill the void. Foremost among them has been the LISP family. And LISP in turn has given impetus to a whole variety of the so called list-oriented or logic programming languages.

"Thirty days hath September, April, June, and November." How might two different simulations languages represent this set of data?

A FORTRAN programmer might well use DATA statements:

```
DATA MONTH (4)/30/
DATA MONTH (6)/30/
DATA MONTH (9)/30/
DATA MONTH (11)/30/.
```

A programmer using the MACLISP-based production rule language called RITA might code this information as follows:

> If the month is April, June, September, or November,
> then the number of days is 30.

Of course, there is a large expressive range in both languages, but these are representative means of encoding our information. The RITA version is verbose in some sense, but the FORTRAN version - to the uninitiated, at least - is stark and forbidding. A non-programmer would probably find the RITA statement perfectly understandable and virtually indistinguishable from English. However, this non-programmer may not be able to make any sense at all of the FORTRAN.

This example seems to stack the cards against FORTRAN. But there are many instances wherein FORTRAN presents effective and readable commands. For instance, the command to compute a new sonar signal excess in FORTRAN is expressed easily in one line which parallels nicely the more conventional mathematical expression.

It must be emphasized, though, that the matter of programming languages is entirely secondary and that only symptoms of deeper issues are revealed in something like the example we discussed above. What is the central issue? What really distinguishes one kind of simulation method from another?

Terry Winograd, in an article entitled "Toward Convivial Computing,"[2] argues that the whole of computer technology has developed in three distinct stages. The first and earliest stage concentrated on the number crunching functions of the computer and computer resolution of immense numerical problems. The second stage was the development of the idea of data processing and of the capability to establish and manipulate data bases whose elements include much that is not strictly numerical. The third stage, one which computer technology is just now entering, is the era of knowledge engineering. With this technology it is the chunk of knowledge, as opposed to the individual number or piece of data, which is manipulated to generate new information and new knowledge.

Characteristic of knowledge engineering is a greater concern for the manner in which knowledge gets into a system, the internal form it assumes within the computer, and the shape in which it is presented to a computer system user. Ideally, the principles of knowledge engineering promise to promote a much smoother and more graceful interaction between computer system and the unsophisticated user.

---

2. The Computer Age: A Twenty Year View, M. L. Dertouzous and J. Moses (editors) MIT Press, 1979, p. 56-72

And what of simulation methods? To a great extent the development of simulation methods has followed the course described by Winograd. The different simulation methods are different by virtue of the raw material with which they work. Physical process simulations naturally operate on numbers; complex simulations of social and economic interactions use items of information from complex data bases; simulations of more complex individual human behavior are naturally knowledge-based. The knowledge required of a human behavior simulation can indeed be quite complicated: it may include both the explicitly known and the implicitly held, the experimental, the intuitive, and the deductive.

But knowledge engineering techniques have the potential to get access to and use profitably many of the different varieties of human knowledge which more traditional methods of simulation might not be able to use, or might be able to use but only in painfully ad hoc ways. The simulation method should be appropriate to the atoms with which the simulation works: if knowledge is the raw material, why not use knowledge engineering techniques? If numbers are the raw stuff, then use existing mathematical modeling techniques.

TRADITIONAL SIMULATIONS FOR TEAM TRAINING

For the team training demonstration system, the functional requirements of several of the simulation subsystems clearly call for a classical mathematical modeling approach. For sonar, radar, and magnetic anomaly detection the safest, most efficient, and most economical means of handling the simulation is to code the set of equations which model the phenomena in some language like FORTRAN. For ASW support personnel, the case for classical simulation is not quite so strong, but since basically data and message-handling activities are involved, and since the support models will all be rather small, it will be most convenient to use a simple simulation of a kind of message passing and message handling network. For the team members, something much different is called for. Just what this might be is discussed in the next section.

KNOWLEDGE-BASED SIMULATION FOR TEAM TRAINING

Confronted with a strong sonar contact with an apparently hostile submarine, the ASWOC must make several decisions in short order. He must, for instance, issue a command for his ship to begin to execute evasive maneuvers before it is in danger from the submarine. In the team training demonstration system, this decision point will surely come up again and again and, if the ASWOC is missing, the ASWOC simulation subsystem itself must recognize the situation, make a decision, and issue the command. How might this be done?

One very appealing approach to this problem uses a _production system_ based on _production rules_. For this example, the relevant production rule would be something like:

_If_ sonar contact with a hostile is made, and
_if_ the contact is X miles from ownship,
then ASWOC should recommend evasive activity.

(The precise form of this rule, because it represents a tactic, is classified, so this rule is more vague than it would appear in the real system.) One advantage of the production rule representation is immediately apparent: production rules make sense to people other than programmers. A subject matter expert, with minimal effort, should be able to understand all the production rules in the form they are used by the program.

Another advantage of the knowledge-based simulation, as exemplified by the production system, is that individual bits of information need only be coded once. Our rule for the ASWOC should serve to aid the ASWOC model, should provide information for the performance measurement system, and should serve to predict for the speech understanding system just what the ASWOC might say next. All this from one rule in one place.

Furthermore, the rule-based simulation should aid in annotating and explaining team member errors. For instance, had the ASWOC failed to recommend commencing evasive maneuvers, the PM system would recognize this, and note that the ASWOC failed to respond according to rule # N.

Of course, there are potential disadvantages to a knowledge-based approach. These are described in Table H-1. There is definitely an element of technical risk involved in knowledge-based simulation at the present time. But what of the alternative? Traditional simulation methods are better known and better supported and are thus, in some sense, less risky, but there is a serious question whether these older simulation methods are adequate to the task of modeling team member performance.

SOME PRECEDENTS FOR KNOWLEDGE-BASED SIMULATION

In the last several years, several knowledge-based systems have been designed and built, and many are now functioning. Early breakthroughs in this area were made at Stanford University where a series of expert knowledge-based programs developed from an initial seed.

The MYCIN system was developed by Randall Davis, Bruce Buchanan, and Edward Shortliffe to provide consultative advice on the diagnosis of and therapy for infectious diseases - in particular, bacterial diseases in the blood. MYCIN is a high performance program which has succeeded in attracting the interest and assistance of medical experts all over the world.

DENDRAL, developed by Bruce Buchanan and Joshua Lederberg, is an expert program designed to aid in the structural analysis of complex molecules by creating and testing hypotheses based on raw mass spectroscopy data. This program is good enough so that it has done "original research" in the sense that it has produced publishable results.

Table H-1. ADVANTAGES AND DISADVANTAGES OF KNOWLEDGE-BASED SIMULATION.

Advantages	Disadvantages
Permits orderly and unified development of large amounts of a task specific information.	Requires time consuming work with subject matter experts to extract relevant knowledge and to formalize it. Difficulty encountered by SME's in coping with this formalization, as well as difficulty in dealing with the necessary introspection.
Facilitates extraction of information from subject matter experts, as well as examination and correction of previously encoded knowledge.	Potentially large memory resources are called for.
Allows relatively rapid modification to the knowledge base by changing rules, adding rules, or deleting rules.	Real time operation is chancey.
Operates well in an interactive mode in explaining decisions, calling for new data, modifying existing rules: capable of being very supportive of PM.	Production rule format is not natural in some cases; knowledge of some kinds is not naturally expressed this way.
Can explain a chain of reasoning and conclusions reached.	Large number of potential production rules are involved - especially if three team members are to be modeled. Overlap of knowledge ameliorates this somewhat, but how much?
Permits "chunking" of knowledge so that each rule is a comprehensible statement of some piece of system knowledge.	Inference procedures, especially ones like backward chaining, occasionally involve long chains of complicated reasoning. Perhaps difficult to track down cause of errors.
Provides capability for dealing with judgmental knowledge and probabilistic reasoning.	
Should (after initial learning experience) aid coding and debugging considerably.	
Provides capability to include meta-rules in a natural way to influence strategy and directions of reasoning.	
Promotes smooth development from a working skeleton to full version.	

TEIRESIAS, developed by Randall Davis, was designed to offer assistance in the interactive transfer of knowledge from a human expert to the knowledge base of a high performance program. Originally developed for use in conjunction with MYCIN, TEIRESIAS has proven to be significantly more versatile. For example, TEIRESIAS also has acted as the knowledge acquisition front end for an investment advisory program.

GUIDON, developed by W. J. Clancey, is a case method tutoring program designed to improve a student's ability to diagnose complex problems in a scientific or medical domain. GUIDON differs from other computer-aided instructional programs in that it has domain - independent rules which guide the presentation of materials. Furthermore, GUIDON teaches knowledge in terms of rules of good judgement, as well as factual knowledge.

Of course, a lot of good work has been done in places other than Stanford. The RAND Corporation, for example, has developed two more-or-less general purpose production system languages called ROSIE and RITA. Philip Klahr and William S. Faught at RAND have developed ROSS (Rule-Oriented Simulation System) which simulates the tactical environment of air warfare in a rather sophisticated way.

At the Naval Ocean Sea Center (NOSC), Dennis C. McCall and Robert J. Bechtel developed STAMMER, a production rule-based system designed to simulate the identification of unknown ships at sea.

The examples cited here are just a small sample indicating the level of activity in the area of expert systems and knowledge-based simulation.

A SAMPLE SOFTWARE ARCHITECTURE FOR A KNOWLEDGE-BASED SYSTEM

One kind of knowledge-based simulation system which might be used to model the ASW team members is described below in a sketchy way. The approach taken here is to use a production rule-based system, but other reasonable choices are possible.

What kinds of knowledge must the system incorporate? Basically, there are three varieties: declarative, procedural, and control knowledge. These three flavors of knowledge combine to form a generalized production system in the following way:

1. The repository of declarative knowledge is a global data base. This data base holds statements which have the basic form: An x is a y with properties p and q. For example, "the ocean conditions are characterized by Beaufort wind scale value v and sea state s."

2. The procedural knowledge is represented by a set of production rules consisting of preconditions required to satisfy the hypotheses of rules followed by the consequences of the hypotheses. When a rule's hypotheses are satisfied, the rule is activated. For example, a typical ASW production

rule might have the form:

_If_ the weapon's danger area is not clear of friendly forces,
then the weapon should not be fired.

When the hypothesis is met (i.e., there is a friendly craft in the way), the rule is activated and, in the absence of other information, the system will decide that no weapon should be fired.

3. Control knowledge is embodied in a control system which selects activated rules, applies them, and modifies the data base accordingly. The select/apply cycle is repeated until some termination condition on the data base is met.

Perhaps the most subtle of these three areas is control. There are a variety of control strategies which might be employed to create the so-called inference engine. Control strategy schemes can be tentative or irrevocable (can or cannot back up from and reconsider previous decisions), forward or backward (proceeding to goal state, or backward from goal to subgoals), decomposable or indecomposable (data base does or does not have separate components which can be handled individually), and order dependent or independent (order in which products or rules are applied is/is not relevant).

The design of an adequate knowledge-based modeling framework for team training requires that the choices of control strategies be made as best possible to support ASW training.

APPENDIX I

A KNOWLEDGE-BASED MODEL OF THE ASWOC

INTRODUCTION AND BACKGROUND

The purpose of this appendix is to sketch a design for a knowledge-based simulation of the ASWOC's activity as part of an ASW team in active pursuit of a submarine. While the focus of most work done under the Team Training Through Communications Control contract has been on three member teams, our emphasis in this appendix will be to look at an approach for modeling just one member of that team. We restrict our attention in this way because it is important, first of all, to see if a knowledge-based simulation is feasible for one team member before committing the resources to design models for all the team members. Secondly, available resources at this time were sufficient only for examining one model in detail. Thirdly, the approach we have chosen uses a structure which appears to be applicable for the other team members as well. Thus, the basic design we present would almost certainly provide the fundamental structures to support a complete design for each team member model.

We focused on the ASWOC because the modeling of the ASWOC's activities seems to require more complexity and more variety than either the ASAC or the ASWFCO models. In part, this is because the ASWOC's job calls for a greater degree of high-level cognitive thinking and decision making, and requires as well knowledge of a significant collection of procedural and manipulative skills. We chose the most challenging model to start with because, at this stage of development, it is important to test a knowledge-based design against a complex facet of the modeling problem to see if the approach is workable, and to get an idea of its potential complexity.

To a certain extent, we have limited the modeling problem by restricting ourselves to that aspect of the ASWOC's behavior involved with choosing and firing a weapon at a known submarine in a known position, and then retiring. This limitation does <u>not</u> apply to the structural design of the ASWOC model, which should be capable of supporting any aspect of the ASWOC's ASW activity. The restriction does apply to the specific enumeration of individual bits of knowledge which the ASWOC will need; to get an idea of the magnitude of this detailed knowledge, we assembled knowledge "particles" for this limited part of the ASW problem to present a sample of the basic knowledge structure.

The design which is presented in the following pages has been developed in the spirit of knowledge-based systems engineering. The basic structure of the design is a modified production rule system which is capable of operating and communicating with an external system which regards the ASWOC model as just one of its own subsystems. For our purposes, we shall concentrate on the ASWOC model per se, and assume that the rest of the system is defined. Where it is necessary or illuminating, we will include some details of the interface between the ASWOC model and the external system.

CHOICE OF A KNOWLEDGE-BASED STRUCTURE

WHY A KNOWLEDGE-BASED STRUCTURE? A number of factors were involved in our decision to model the ASWOC's behavior with knowledge engineering techniques as opposed to more traditional procedural simulation techniques. (A "procedural simulation technique" is one which represents each activity or process to be simulated as a strict sequence of actions to be followed, one after another, possibly contingent on intervening decision logic to determine which of several sequences is to be followed. A knowledge-based simulation technique, in contrast, does not pre-define a sequence of actions to be followed.) Our reasons for following the knowledge engineering approach are described in detail in other sections of this report, but we will summarize the main points.

Knowledge-based systems:

a. Collect, retain, and use knowledge relevant to system functions in a manner which is much closer to human functioning than traditional methods. Thus the basic structure is much more comprehensible to human non-specialists.

b. Make it possible to code significant knowledge just once for use in several contexts. This contributes to internal consistency, ease of design and maintenance, greater comprehensibility, smoother development, and facilitated correction of errors.

c. Are capable of re-tracing their operations and explaining how their decisions are arrived at. This makes debugging of the systems significantly easier at all levels.

d. Greatly facilitate an incremental developmental process whereby an initial functioning core can be fleshed out gradually, with new capabilities and new knowledge added piece by piece.

The advantages of using a knowledge-based approach to model the ASWOC are considerable. The ASWOC's behavior is complex, and traditional means of simulating his activities using a basically procedural approach would probably produce a very large body of unwieldy code which would be hard to debug and harder still to maintain. A knowledge-based approach offers the capability to cut through the complicated interactions inherent in the procedural approach by letting the system respond dynamically to the environment as it changes.

WHAT KIND OF A KNOWLEDGE-BASED SYSTEM? Once we had made the decision to take a knowledge-engineering approach to the problem of modeling the ASWOC, we had to decide what kind of a knowledge-based system paradigm was best for the ASW team training situation. Over the past fifteen years, a number of generically different approaches to knowledge-based programming have developed. Generally, these approaches have evolved around certain kinds of problems (e.g., cognitive modeling, understanding stories, simulating short term memory,

modeling the know-how of an expert, etc.). It was apparent from the beginning that one kind of knowledge-based formalism was an especially good candidate for ASW team member modeling, but we considered other possibilities carefully to assure ourselves that our initial predilection had an adequate foundation in theoretical foundation. We chose then to proceed with our original favorite and use a production rule based system (production system for short) to model the ASWOC. Our justification for this choice will be explained later, after we have sketched a description of a generic production system.

Production systems were introduced by the mathematician Emil Post in 1943 (see reference [4]). For Post, a production system was a general computational mechanism which had strong potential for the study of formal systems. Since their introduction, production systems have undergone a great deal of development, their methodology has expanded considerably, and they have been applied to an extremely diverse collection of problems.

A pure production system may be looked at as a combination of three basic components: a set of rules, a data base, and an interpreter for the rules. In the purest and simplest design, a rule is an ordered pair of symbol strings with a left-hand-side and a right-hand-side; the rule set has a predetermined total ordering; and the data base is just a collection of symbols. In this simple design, the interpreter works by scanning the left-hand-side of each rule in turn until one is found which matches some element of the data base. At that point, the symbols matched in the data base are replaced with those found in the right-hand-side of the applicable rule, and scanning either continues with the next rule or begins again from the first. The rule selection function can also be viewed as a chained sequence of <u>modus ponens</u> operations.

To put some flesh on these bare bones, consider the following example. Let there be three production rules in our system:

P1. If there are ducks on the pond, then the fish are uneasy.

P2. If the fish are uneasy, then it is raining.

P3. If it is raining, then there are ducks on the pond.

Suppose our data base consists initially of the string "it is raining". Further, assume that the rule interpreter is set up to apply whatever rules are applicable on each cycle, and to replace the current data base entry with the right-hand-side of the applicable rule.

After the first rule interpretation cycle, rule P3 has been applied, and the data base holds "there are ducks on the pond." After the second cycle, rule P1 has been applied and the data base holds "the fish are uneasy." At the end of the third cycle, rule P2 has been applied, and the data base once again holds "it is raining." Clearly, this pattern is repeated indefinitely in this example. Note that the production rules can be considered formally

as left-hand-side, right-hand-side ordered string pairs--e.g., it-is-raining, there-are-ducks-on-the-pond--or as ordinary conditional statements of the form condition-action or hypothesis-conclusion. Also, notice that the data base can be thought of as the state of the world at any given instant.

We will describe the production system architecture we have chosen for the ASWOC model in detail in the next section of this appendix. Since it is not a pure production system, we will discuss at the same time those few additional structures we need to make the model complete. In the remainder of this section, we will address the issue of the appropriateness of a production system for modeling the ASWOC.

WHY PRODUCTION SYSTEMS PROVIDE A GOOD PROTOTYPE. Program designers have found that production systems easily model problems in some domains, but are awkward in others. From a purely theoretical point of view, production systems and traditional procedural systems are formally equivalent, because both in turn are formally equivalent to a simple Turing machine. So the question is not which approach can do the job (since if one can, they both can), but instead which approach offers the greater economy of design, ease of implementation, and gracefulness of operation. Randall Davis and Jonathon King surveyed the breadth of applications of production systems (1977), and they offered some observations about problem domains in which production systems could be most effectively used. In their view, production systems appear to be most useful where it is important to detect and deal with a potentially large number of independent states, in a system which requires a broad scope of attention, and the capability of reacting swiftly to small changes. In addition, they note that where knowledge of the problem domain falls naturally into a sequence of relatively independent "recognize-act" pairs, production systems offer a convenient formalism for structuring and expressing that knowledge.

The modeling of the ASWOC, ASAC, and ASWFCO seems to fit very naturally into a production rule system format. To be sure, a number of additions and modifications to the pure production system structure appear to be necessary, but the basic structure is more than compatible with the requirements and the demands which these models make. If we focus once again on the ASWOC model, we can point to some specific reasons why the production system idea is so appropriate.

The two features of a production system which make it suitable for modeling the ASWOC are the simple and practical form of the rule structure and the openness of the control structure. The rule structure seems very nearly ideal for representing the ASWOC's knowledge. A great deal of the ASWOC's know-how is most naturally expressed in condition-action form. Furthermore, the dynamic nature of the ASWOC's environment dictates an approach which is responsive and reactive: there are a very large number of possible changes in the environment, and they must be responded to actively in a short period of time. In addition, instruction manuals typically convey information in a form which is akin to that of production rules, and a functioning ASWOC

also tends to describe his functions in those terms. The real test, however, comes when a subject matter expert tries to reduce his complex knowledge of the ASWOC's job into production rules.

We performed this test for the small segment of the ASW problem which we have already described, and the production rules which evolved are shown in Appendix D. The subject matter expert had some difficulty in describing the ASWOC's functions at such a basic level, but several sessions with a knowledge-expert served to draw out those basic bits of knowledge which the subject matter expert knew so well that he could not easily identify them explicitly. The process of identifying the rules was somewhat tedious, but the equivalent process for a more traditional simulation system would hardly be less so. In the end, we arrived at a good core of production rules which appear more than adequate for the first step in an incremental development. The subject matter expert divided the rules into two basic sets: those with a definite "context," and floating rules. As presented in Appendix D, the rule structure appears rather constrained since only a few rules appear to be potentially active at one time. In part, this reflects constraints in the basic ASW situation: if A is true, then actions B, C, D, and E must follow pretty much in order. However, the floating rules are applicable at any time, and these rules will undoubtedly break up the rigidity which now appears to be present in the rule structure. Those familiar with production system development (see, for example, reference McDermott, 1981) estimate that the initial collection of production rules gathers from one-third to one-half of the number of rules present in the finished system. We would anticipate that the number of floating rules, in particular, would increase significantly as the system develops and more rules are added as needed.

A second strong advantage of a production system approach to modeling the ASWOC is the openness of the control structure. Since the ASWOC must function in an open-ended world, the ASWOC model must be adaptable enough to function in an emergent situation. This kind of situation is handled well by the production system control structure. Production systems are characterized by a sensitivity and a reactivity which arises from the continual reevaluation of the control state. This is the property which has been sometimes described as the "openness" of production rule based systems. This openness is characterized by the principle that "any rule can fire at any time," which emphasizes that, at any point in the computation, any rule could possibly be the next one selected, depending on the state of the data base at the end of the current cycle. Compare this to a normal situation in a traditional procedural simulation where this principle is manifestly untrue: it is simply not the case there that, depending on the contents of the data base, any procedure in the entire program could potentially be the next one invoked.

In the next section, we describe in some detail a specially tailored production system to model the ASWOC.

THE GENERAL ARCHITECTURE OF THE ASWOC MODEL

In this section we will review the functional requirements for the ASWOC model, and then describe a production system based design for meeting these requirements. Our attempt here is to discuss a top-level design; thus, many issues of implementation are not taken up at all. However, a few key implementation questions are discussed in the next section.

THE REQUIREMENTS. The primary functional requirement for the ASWOC model is that the model should be capable of operating in the team member environment in place of a human ASWOC, responding to situations as they arise with appropriate actions and suitable communications. The ASWOC model constitutes a well-defined subsystem of the full team training system which is, to some degree, self-contained. Nonetheless, the ASWOC model must have the capability to interact with the external system, and thereby with other team members or other team member models.

A secondary requirement of the ASWOC model is that it support the first stage error detection requirements as well as some obvious extensions to traditional forms of performance measurement. The idea is that the ASWOC model, as a nominal expert in the ASWOC's job, should provide the performance measurement system with information about several alternative correct sequences of decisions, actions, and communications with measures of their adequacy. In this capacity, the ASWOC model must act in a shadow role, and its presence should be invisible to the human ASWOC.

Since the team training system, as envisioned, is designed to develop incrementally, and since part of the focus of the system will be its use as a research tool, the ASWOC model is subject to a third requirement. This requirement provides that the ASWOC model be capable of supporting the validation of performance measurement, as well as of monitoring its own functioning and maintaining its own internal consistency.

In summary, the functional requirements for the ASWOC model are the following:

1. The ASWOC model must be capable of taking the place of the human ASWOC in the team training systems, making decisions, initiating actions, and producing communications as a human might.

2. The ASWOC model must provide a standard of nominally correct ASWOC behavior for the performance measurement system.

3. The ASWOC model must support incremental growth, modification, and tuning; moreover, the model should be capable of supporting the validation of performance measurement.

THE OVERALL CONCEPTION OF THE MODEL. The core of the ASWOC model shall be a simple production system consisting of a set of rules, a data base, and

a control structure. The basic core would be adequate if we were building just an ASWOC expert model, but, by itself, this would satisfy only part of our first functional requirement. The complexity in the full task of meeting all the functional requirements calls for a significant embellishment of the form of a pure production system. The basic ingredients are the same, but there are additional structures and even the basic structures have additional levels of complexity.

Our design for the ASWOC model encompasses the following features:

1. A complete ASWOC model consisting of the following submodels: ASWOC nominal, ASWOC non-standard, and ASWOC performance measurement.

2. A rule structure consisting of three different kinds of rules.

3. A control structure capable of managing three inference streams.

4. A single unified data base.

5. A "blackboard" for recording rules invoked, state of the world information, and intra-system messages.

6. An activation key limiting access to rules to the proper inference stream.

7. A capability to identify an inference with the inference stream responsible for it.

The term "inference stream" means a sequence of applications of rules of one particular kind.

At least two of the features of the ASWOC model run against the spirit of pure production systems. These are the features which control access to rules (design feature #6) and which, so to speak, identify the "agent" responsible for each inference (feature #7). Both of these items tend to inhibit the autonomy of the rules and, to some extent, to restrict the openness of the rule control structure. Nonetheless, the reasons for adopting these features seem compelling.

The ASWOC expert--that is, the standard model of nominally correct ASWOC behavior--is represented by one distinguished subset of the total set of rules. Once each rule evaluation cycle, the control system evaluates all of its own set of rules (meta-rules or strategy rules, which constitute a second distinguished set) to determine which subset of the ASWOC's rules should be potentially active during that cycle. The control system then evaluates all the applicable ASWOC rules, modifies the data base for those rules which are invoked, records the inferences made on the blackboard, and "takes action" or "initiates communication" by making suitable entries on the action-item area of the blackboard.

The blackboard has several functions which will be described in greater detail later. Briefly, the blackboard offers a summary of the current state of the ASWOC model's world to mediate communication with the external system, to provide comprehensive snapshots of the system's behavior for debugging purposes, and to retain a complete history of events to permit extensive off-line automated performance measurement.

On-line performance measurement shall also be provided. A third distinguished subset of rules shall be performance measurement rules, and these rules shall be capable of being evaluated once each rule evaluation cycle. (We do not offer a detailed design of the performance measurement subsystem in this appendix; instead, we focus upon the fundamental representational framework which shall support automated performance measurement.) The overall control structure shall admit the possibility of different cycle lengths for each kind of rule evaluation (ASWOC rules, strategy rules, performance measurement rules) to facilitate an optimal mesh of the different kinds of rule evaluation.

The ASWOC model is capable of functioning in two modes. First, it can function in place of the ASWOC to simulate the actions and decisions of a human ASWOC. Secondly, it can act as a shadow ASWOC when the human ASWOC is present. In this case, the model can make decisions and determine actions, but it will merely record them and not carry them out. Performance measurement typically operates in this latter case, and it is here that the human ASWOC's behavior is measured against the standard ASWOC model behavior which in turn is derived from a nominal set of rules. To validate performance measurement, it would be desirable to exercise the performance measurement rules under controlled conditions. Indeed, this is possible under the first mode of operation of the ASWOC model. The standard ASWOC model can operate to create a baseline of nominal behavior, and an autonomous non-standard ASWOC model could operate on an augmented, diminished, or modified set of rules. In this case, the performance measurement system would measure one (imperfect) non-standard model against the standard model of nominal behavior. This approach allows for the tuning of the performance measurement system under circumstances where all variables are under control. It also provides a means of identifying and correcting the deficiencies in the standard ASWOC model, and of reducing its unnecessary rigidities.

In the paragraphs which follow, we will discuss the rules, the control structure, the data base and the blackboard in greater detail. Then we will give a couple of examples of how these system components operate together as a whole.

COMPONENTS OF THE SYSTEM. The basic components of the ASWOC model are rules, control structure, data base and blackboard. This section is devoted to a description of each of these elements; it concludes with two examples of the model in action.

Rules. Production rules make up the heart of the ASWOC model; they represent its core of knowledge and its fundamental atoms. The ASWOC model contains three distinct kinds of rules. All of these rules constitute a single pool of rules which can, in principle, be applied by any "inferencing agent" (that is, one of the inference processes being managed by the control mechanism). The first rule type is the basic condition-action rule which describes a set of ASW conditions together with actions to be taken when these specific conditions occur. The second rule type is a strategy rule or a meta-rule which is used by the controlling mechanism to determine which subset of ASWOC rules should be active at any given time. The third rule type is the performance measurement rule which compares ASWOC actions against the comparable recommended actions of the standard ASWOC model.

We shall not address the precise format of the rules here. Some comments are made about their formal structure in the next section, but here we will indicate only what their constituent elements are. Each rule shall consist of:

1. An activation key. This is a symbol which identifies the rule to each "inferencing agent" as applicable or non-applicable.

2. A left-hand-side, condition, or hypothesis. This is a symbol string which describes the circumstances under which the rule can be invoked.

3. A right-hand-side, action, or conclusion. This is a symbol string which describes the change to data base which must occur as a result of the application of the rule.

4. A confidence value. This represents a relative judgment about the appropriateness of the application of the rule. It is intended to provide a (situation specific) conflict resolution parameter for the control mechanism, and it should be capable of being computed dynamically.

Although the rules all reside in a single pool, it should not be possible for all inferencing agents to access all the rules all the time. For example, the standard ASWOC model has no need even to attempt to evaluate performance measurement rules since they are simply not relevant to the ASWOC's job. Furthermore, the standard ASWOC model has no need even to evaluate the non-standard ASWOC rules, since they lie outside the boundary which defines standard behavior. The reason that all the rules do lie in a common space is that many rules ought to be shared by the different inferencing agents. For example, both the non-standard ASWOC model and the performance measurement model might well invoke standard ASWOC rules.

The activation key allows controlled access to the rules. Each inferencing agent has a key signature which allows it access to a given subset of the rules. The key signature can be changed dynamically to enlarge or change

the collection of accessible rules depending on the state of the environment. The activation key offers a capability of control which will permit the inferencing agents to test appropriate rules at appropriate times. The activation key itself is under the control of strategy rules (or meta-rules), and is thus directly connected to the system control functions.

The data base which the ASWOC model uses is much like the simple data base of a pure production system, but there are two notable differences. Although the data base holds all the symbols corresponding to the invocation of any rule (and thus indicates that some inferencing agent has applied a rule to produce it), each symbol string generated by the successful application of the rule carries an identification tag that indicates which inference process generated the symbol. For example, if the non-standard ASWOC model invokes the rule

"If a weapon is fired, the bridge should be notified of the weapon firing bearing."

when the data base holds the string for "a weapon is fired" and a tag which indicates that the non-standard ASWOC model created this symbol string, then a new symbol string is created in the data base for "the bridge should be notified of the weapon firing bearing", <u>and</u> this symbol string is also tagged with the non-standard ASWOC's identification mark. This allows the non-standard model to proceed relatively independently of the standard model in generating its own strings of inferences without affecting the functions of the nominal ASWOC model.

<u>Control Structure</u>. The basic functions of the control structure shall be to direct the application of the production rules and to maintain the interface with the external system. The control structure shall be capable of maintaining three distinct inference streams and, thereby, of coordinating three different "agents" who can apply rules. (The idea of quasi-independent "agents" who can act by choosing rules, applying them, and modifying their memories correspondingly offers a useful way to think and talk about this multifaceted control structure.)

Each basic rule control cycle for each agent can be broken down into two phases: recognition and action. The recognition phase can be further subdivided into selection and conflict resolution operations. In the selection process, one or more potentially applicable rules are chosen from the basic pool of rules, and are then passed on to the conflict resolution algorithm, which chooses one of them.

The choice which occurs at this selection phase is fundamental. At this stage, the control mechanism operates a symbol scanner which scans the left-hand-sides of all rules applicable for a given agent at that time, and collects all rules which evaluate successfully. Then rules whose confidence values lie below a certain threshold value are rejected, and the remaining rules are passed on to the conflict resolution algorithm.

The conflict resolution algorithm must decide which of the applicable rules will actually be invoked. The purpose of conflict resolution is to see that the actions taken by the model have a well-defined direction toward an overall goal; if rules were to be invoked whenever they were applicable, the agent's "attention" might well wander from one direction or activity to another without focus. The overall goal and subsidiary subgoals are embodied in two ways. First, as confidence values attached to the rules: this gives a means of rendering one applicable rule more desirable than another. Secondly, as an algorithm to generate confidence values automatically: this provides a means of shifting smoothly from one subgoal to another as the situation evolves.

When it is finished, the conflict resolution algorithm recommends one or more rules to apply. Then the action phase begins. The chosen rules are applied, the data base is modified based on the right-hand-side of the rules invoked, and the contents of the blackboard are updated.

Control of the blackboard is a significant aspect of the control structure's responsibilities inasmuch as the blackboard maintains all the communication links with the external system. From one section of the blackboard, the control mechanism can extract new state-of-the-world information as well as messages directed to the ASWOC by other team members or by other simulated personnel. On another section of the blackboard, the control mechanism can record messages or commands directed toward other parts of the system.

Data Base. The data base for the ASWOC model shall consist of two parts. The largest part shall be comprised of an area of working memory where the symbol strings generated by the invocation of rules shall be recorded. Periodically, the working memory will be cleaned up by a garbage collection algorithm whose function is to restore and re-allocate memory space which is holding expired symbol strings.

The second part of the data base shall consist of one panel of the blackboard where state-of-the-world information is stored. Both new messages and current environmental data are stored in this area of the blackboard. Information contained in the messages is eventually moved to working memory, but current information about the features of the world which the ASWOC cannot change directly (e.g., submarine position, ownship position, sonar data, etc.) shall always remain recorded in this panel of the blackboard. The control mechanism shall maintain the blackboard internally; a system utility routine shall control the external system's use of the blackboard (i.e., reading from or writing to).

The Blackboard. The notion of an abstract blackboard as a software device for recording system information is probably due to the developers of the HEARSAY-II speech understanding system at Carnegie-Mellon University (Erman and Lesser, 1980). Originally, the blackboard was supposed to record hypotheses made by the various knowledge-source components of the system as an unknown utterance was being analyzed. In this way, separate elements of a large

system could "share their ideas" at the same time that their interactions were being kept to a minimum. In our case, the blackboard is more of a data tablet, but it also functions very much as a communication device. It provides one panel for communications received from the external system, and one panel for messages or commands directed to the external system. Another panel records the inferences and actions taken (or recommended) by the nominal ASWOC model. A fourth panel either records the human ASWOC's activities (if the system is operating in this mode), or, in another mode, records the inferences made and actions taken by the non-standard ASWOC model. A fifth panel records the invocation of performance measurement rules. Table I-1 summarizes these blackboard features.

TABLE I-1. THE BLACKBOARD FEATURES.

Panel 1.	This panel holds state-of-the-world information as well as new messages which have just been received from the external system.
Panel 2.	This panel holds a record of inferences made by the nominal ASWOC model and actions which are taken or recommended by the model.
Panel 3.	This panel holds either a record of the human ASWOC's activities or a record of the non-standard ASWOC's inferences made and actions taken.
Panel 4.	This panel maintains a record of the performance measurement rules which were invoked.
Panel 5.	This panel holds a record of messages transmitted to the external system as well as commands issued by the ASWOC model.

Besides providing a necessary medium for intra-system communication, the blackboard serves at least two other significant functions. The first of these is as a debugging aid. To disentangle the several inference streams operating, and to understand complex system interactions, the system can simply take periodic snapshots of the blackboard and store them on disk for

off-line analysis. This would allow the software engineer to reconstruct complicated situations, follow out the inference streams, and trace communications to and from the ASWOC model.

The third function of the blackboard is to support off-line automated performance measurement. Since both human ASWOC actions and recommendations of the nominal ASWOC model are recorded on the blackboard, a sequence of snapshots of the blackboard would provide a substantial exercise summary upon which many varieties of measures of performance might be tested.

Examples. The full enhanced production system design which we have described is relatively complicated, and we have really only sketched the abstract skeleton of a system which will be capable of many kinds of "intelligent" (or intelligent-seeming) behavior. To give a better idea, or a better feel, of how the system will eventually function, let us consider two simple examples which will give a flavor of the dynamic character of the ASWOC model.

For the first example, let us consider a situation where the human ASWOC is present and the ASWOC model is functioning as a nominal standard of behavior. In a very simplified way, we will set up the current state of the system: rules, blackboard status, and data base.

Let us assume that the ASW team has localized the position of a hostile submarine, has put the ship in a position to fire a weapon at the submarine, has cleared friendly tracks from the weapon danger area, and has fired a torpedo at the submarine. The human ASWOC is in control of the situation, and the ASWOC model is acting in its shadow capacity. The ASWOC model will determine a course of action to follow, but the human ASWOC makes his own decisions and the ASWOC model must record its own recommendations and follow along behind the human ASWOC. The complete ASWOC model has a large data base, a significant set of rules, and a large blackboard area. But, to make the example manageable, we will just look at little pieces of the big structures.

Assume that the ASWOC model data base consists of the following strings:

Torpedo-has-been-fired-at-submarine

Firing-bearing-is-XXX

Weapon-danger-area-has-been-cleared

Suppose that the collection of ASWOC rules includes these rules which are active at the present time:

P1. If a weapon has been fired at the submarine, then the SAU commander should be notified of the firing bearing (ANA3, 0.90).

P2. If a weapon has been fired at the submarine, then ownship should retire to a safe distance (ANA3, 0.95).

P3. If ownship is to retire to a safe distance and the submarine is off the starboard bow, then ownship must turn 90 degrees to port and accelerate to 20 knots (ANA2, 0.92).

P4. If ownship is to retire to a safe distance and the submarine is off the port bow, then ownship must turn 90 degrees to starboard and accelerate to 20 knots (ANA2, 0.92).

P5. If ownship is to turn or change speed, then the bridge must be notified of desired course and speed (ANA1, 0.95).

Here the rules are in the usual condition-action format and two additional elements are included. These are: the activation key describing who has access to the rule and when, and a confidence value which is a dynamic measure of the priority of the rule. (We assume here that this confidence value is a kind of subjective probability measure with a value between 0 and 1 and with larger values indicating higher priorities.)

Furthermore, we assume that the blackboard contains the following information:

Submarine is at range RRRR yards and bearing YYY degrees

Submarine speed is SS

Ownship course is CCC

Ownship speed is S

Sonar contact with submarine is strong

In addition, there are performance measurement rules which are active. Assume, for simplicity, that there are only two involved here.

M1. If a weapon is fired, then the ASWOC must notify the SAU commander of the correct firing bearing (PM3,0.80).

M2. If a weapon is fired, then the ASWOC must command a turn and a change of speed which moves ownship to a safe area (PM3,0.90).

Now we turn the system on, and watch the situation evolve dynamically. Suppose that the ASWOC model starts with an activation key value ANA* (so that any rule with activation key value beginning ANA is applicable). The control mechanism evaluates the applicable rules. (All the rules listed are potentially applicable since their activation keys all match the ASWOC model's own.) The rule interpreter determines that rules P1 and P2 are satisfied. The conflict resolution algorithm determines that rule P2 has the higher priority, and thus it is activated. This rule's activation key is then changed to ANO to avoid having it evaluated again on the next cycle.

The string "ownship-should-retire-to-a-safe-distance" is written to the data base. Meanwhile, the blackboard is updated with new values of the submarine's range, bearing, and speed, as well as ownship course and speed and the status of sonar.

On the next cycle, the applicable rules are again evaluated. This time rule P1 is still applicable, and rules P3 and P4 have become applicable. The conflict resolution algorithm chooses rule P3 or P4 contingent on the position of the submarine. (This really requires another rule--or an addition to P3 and P4--to determine whether the submarine is to the port or the starboard side depending on the blackboard information.) The ASWOC model then recommends a turn and a change of speed. (This recommendation takes the form of a message on the blackboard intended for the bridge.) Since the human ASWOC is present, all the ASWOC model's "actions" will be recommendations for action, and will be recorded for use by the performance measurement rules.

When rule P3 or P4 is applied, the activation keys of both rules are reset. The blackboard is updated with new position and speed information for ownship and the submarine. Furthermore, the data base is updated to add the string "ship-is-to-turn-90-degrees-to-starboard(port)-and-accelerate-to-20-knots".

On the next cycle, rules P1 and P5 are found to be applicable, and rule P5 has greater priority. Thus it is invoked, and a message is written to panel 5 of the blackboard directing the bridge to turn the ship 90 degrees to port (starboard) and accelerate to 20 knots.

Finally, on the next cycle rule P1 is applied. This causes another message to be written to panel 5 of the blackboard. The message this time is directed to the SAU commander and it informs him of the weapon firing bearing.

So far, we have described only the recommendations which the ASWOC records as the human ASWOC is actually responding to the situation. It is possible, for example, that the human ASWOC chooses to inform the SAU commander of the weapon firing bearing before ordering ownship to proceed to a safe area. In this case, the ASWOC model should record its own choice on panel 2 of the blackboard, but should then continue to follow along with the human by noting that the rule P1 has been invoked, and basing its further actions upon that.

The performance measurement rules M1 and M2 indicate that getting the ship to a safe place has priority over speaking with the SAU commander, and it would note in panel 4 of the blackboard that the human reversed this priority.

A weak human ASWOC might need help deciding what to do after firing a weapon at the submarine. In this event, the ASWOC model is capable of using the rules at its disposal to construct a prompting message like: "Since a weapon has been fired, the ship should be moved to a safe place."

Our second example starts with the same setting as the first example, except that the mode of operation of the system is different. This time we will assume that there is no human ASWOC present, and that the nominal ASWOC model is acting as the ASWOC in the team. Let us suppose that we are trying to verify that the performance measurement rules M1 and M2 are applied correctly, so we will set up a non-standard ASWOC model with access to rules P1 through P6 plus the additional rule:

> P7. If a weapon has been fired at the submarine, then the weapon should be followed in to the submarine to put ownship in position to fire a second weapon (ANS3,0.98).

With this rule present, the non-standard ASWOC model will apply it at once in preference to P1 and P2 (since its priority is higher) and will not retreat to a safe distance. The nominal ASWOC model, however, will invoke rules P2, P3 (P4), P5, and P1 and thereby recommend getting to a safe area while notifying the SAU commander of the weapon firing bearing. The performance measurement system then notes that, although a weapon has been fired, the ship has not moved to a safe area.

SOME COMMENTS ABOUT IMPLEMENTATION

The ASWOC model is a complex entity which consists of several distinct but interacting parts. To go from the design outline which we have presented here to a complete ASWOC subsystem, one must proceed deliberately. In this section, we will sketch an implementation plan which focuses on developing an expert ASWOC model as an initial goal with other system features added incrementally. This approach should produce a working system fairly early in the process so that a subject matter expert can evaluate the model's expertise, modify rules as necessary, and recommend new rules as gaps in the model's knowledge become apparent.

Our emphasis in this implementation plan is on incremental development. At this stage in the development of expert system technologies, extra effort should be made to evaluate the system as it grows to spot potential problems early. The design we have presented offers a good opportunity to use the advantages of incremental development in both technical and management contexts. Technically, an incremental approach is likely to provide a smoother implementation with clearer milestones and more definite baseline subsystems. From the manager's perspective, the incremental approach should provide more obvious and more frequent points for management review of the developing product.

The first stage in the development of the ASWOC subsystem is to implement an expert model of the ASWOC independent of the external team training system. Communications with the model at this stage would be done by keyboard entry; this would also serve to simulate communications with other members of the full ASW team. In this way, the early focus would be upon building, testing, evaluating, and correcting a basic model of the ASWOC's operational knowledge.

Because this knowledge is embodied in self-contained rules, a very limited ASWOC model could be brought up first with a small set of rules, and then new rules could be added slowly to broaden the knowledge base.

The initial development will require a preliminary control structure, an early form of the blackboard, the data base, and a basic core of ASWOC rules. Very early in the process, there will be a need to decide upon a format for the machine representation of the rules, as well as a need for an auxiliary program to translate English language forms of the rules into internal machine format, and vice-versa. Our recommendation at this point is that the rules be represented as an ordered four-tuple of symbols:

(K,L,R,C)

where K is the activation key, L is the left-hand-side (condition) of the rule, R is the right-hand-side (action) of the rule, and C is the confidence value or priority of the rule.

Once a basic ASWOC model is running, the subject matter expert can work with the model to evaluate its judgments and recommend new rules. At this stage, the standard or nominal ASWOC model should be regarded as tentatively complete, and that should be the first baseline for the system.

The next phase of development should be the expansion of the basic control structure to permit maintenance of three different inference streams operating over three potentially different cycle lengths. During this phase, all of the features of the blackboard should be implemented and tested as much as possible.

The third phase of development should be the inclusion of the standard ASWOC model into the broader context of the more sophisticated control structure. At the same time, the capabilities for the parallel operation of a non-standard ASWOC model should be checked out. Since all of the prerequisite structures (blackboard, control structure, rule base) have been prepared by this stage, the non-standard ASWOC model should be functional, and its activities could be studied now by injecting rules unique to it.

The fourth stage of development should be the inclusion of performance measurement rules. By now, the control structure already has the capability to engage the performance measurement rules and record the results on the blackboard. It is anticipated that there will be a significant amount of test and evaluation performed at this point during which the operation of the performance measurement rules would be scrutinized, the standard ASWOC rules tuned, and the coordination activities of the control structure extensively checked out.

The final stage of development should be the integration of the ASWOC subsystem with the rest of the team training system.

CONCLUSIONS

In this appendix we have presented an outline of a design for a knowledge-based ASWOC model which is intended to function as a subsystem of the full team training demonstration system. The fundamental structure of the ASWOC model is based on an augmented production rule system wherein the basic components of a simple production system are supplemented with additional structures. Our intent in this design has been to show that a production system provides a sound basis for the simulation of a human ASWOC's activities, and that the production rule based approach may well be superior to traditional procedural approaches. Our design should indicate at least the possibilities which are inherent in a knowledge-based simulation of the ASWOC.

APPENDIX J

ANALYSIS OF COMMUNICATIONS IN THE TRAINING ENVIRONMENT

While the importance of good communications in the CIC environment is widely appreciated, the design of a training system requires specific information about how communications affect mission outcome. Access to ASW training tapes was gained through the Navy Personnel Research and Development Center (NPRDC) San Diego. From these tapes, three exercises which represented good, average, and poor overall performance of the same type training exercise were selected and transcribed. The intent was to determine if mission success was related to communications. It was found that in fact, the ship that had a smooth exchange of vital information had far better success than did the ship that did not have a smooth exchange. More importantly, the analysis revealed that the mission outcome was indeed reflected in the communications.

To conduct the analysis the communications were broken down by circuit. Ship 1, judged to be good, attacked the submarine, and all stations were involved as a team, keeping each other advised of all pertinent information. Ship 2, judged to be average, attacked the submarine and was therefore successful in their mission, but many times all stations were not aware of what was going on or the evaluator's intention. This was because of a communications breakdown between stations. Ship 3, judged to be poor, had very little team interaction. In fact, when UB did make an attempt to communicate, there was no response from the other stations. In this case the ship was not successful in attacking the submarine and was attacked. These communication exchanges or lack of exchanges will become obvious as one reads the communication transcript.

A key to the transcriptions which follow is provided in Table B-1. In the following paragraphs some specific details of the transcriptions are discussed.

GOOD COMMUNICATIONS - SHIP 1

As the transcription in Table B-2 shows, there was a running dialogue on Ship 1 between the evaluator and UB who acted as the filter for sonar. The evaluator kept UB advised of all contacts, intentions, and accepted communications to gain or hold contact. UB kept the evaluator informed of the contact's estimated position, probable course, and speed. Ship 1 displayed excellent team behavior in the constant comparison made between CIC and UB to arrive at the best solution. Below are some of the internal and external communications and comments on correctness.

Example 1:

From CIC to UB "Another MAD man 262 10900 L2 weapon away safe time 23."

From UB to CIC: "That's a pretty radical jump. I don't think he can make that."

From CIC to UB: "Yeah, I hold him 022 14 Kts."

This good exchange ensured that both UB and CIC shared the same estimated position of the submarine.

Example 2:

From CIC to UB: "Do you have an estimated position on him?"

From UB to CIC: Roger, 268 8500 should be coming into sonar range in a minute now."

From CIC to UB: "ASAC is holding about the same."

Here the evaluator not only compared the information from UB and CIC, but from the aircraft as well. This was very good team behavior.

Example 3:

From RN to CR: "Contact's estimated position 272 6800 from RN."

Frequent communications like this kept the other ship of the SAU advised of the action and directed his movements.

Keeping the assist ship advised of even estimated positions is always a good idea so that the assist ship can position himself to assist or detect the contact.

Example 4:

From RN to CR: "Scramming L2, H3 to the north. Assume brother if you are hot."

The assist ship should have assumed the duties as attacking ship when she got contact. In this communication, the training ship demonstrated good control and team work by notifying the assist ship of the helicopter's movement and giving the assist ship the opportunity to become the attacking ship.

TABLE J-1. ABBREVIATIONS, ACRONYMS, AND PROSIGNS.

The following abbreviations are used in Tables J-2, J-3, and J-4.

Abbreviations	Meaning
A/C	Aircraft
ANS	One-half of a whole number, e.g., 1500 = 1 ANS
AR	Out
AS	Form a surface attack unit (SAU) (when appearing in the text)
AS	All stations (when in the TO - FM column
A/S	Assist ship
ASROC WHITE	Ships individual ASW condition meaning Active Beam to Beam Search
AX	Call sign of the officer in tactical command
BF	Call sign of the protected unit
BNG	Bearing
BR	Bridge
BT	Break (new subject)
CIC	Combat Information Center
CORPEN J	Type of turn
CR	Call sign of the assist ship
C/S	Call sign
Desig	Designate
DR	Call sign of exercise ship 2
ETA	Estimated time of arrival
Form Y	Type of formation
H3	Dipping helo call sign
IMX	Immediate execute
ISA	I say again
K SP	Indicates a speed range, e.g., 18 - 22
K	Over
KTS	Knots
L2	Call sign of the LAMPS helo
LY	Call sign of exercise ship 3
M speed	MY speed
M Corpen	MY course

TABLE J-1. ABBREVIATIONS, ACRONYMS, AND PROSIGNS, CONT.

Abbreviations	Meaning
PK	Computer estimated position of the contact
RAR	Roger out
RN	Call sign of exercise ship 1
RNG	Range
SAC	Scene of action commander
SAU	Surface attack unit
SON	Sonar
SP	Speed
STBY	Standby
TDA	Torpedo danger area
TSR	Tactical sonar range
TURN Z	Indicates zigzag plan (when followed by a desig and letter to indicate which zigzag plan)
UB	Underwater battery
X	Execute
XTF	Execute to follow
---	Tack (used to separate signals to avoid confusion)

TABLE J-2. COMMUNICATIONS IN SHIP 1 - ABOVE AVERAGE PERFORMANCE
(Analyst's comments in brackets. See list of abbreviations in Table J-1)

SHIP 1

1JS TO	1JS FM	1JS COMMUNICATIONS	61JS TO	61JS FM	61JS COMMUNICATIONS	SAU REPORTING TO	SAU REPORTING FM	SAU REPORTING COMMUNICATIONS
	SON	Request permission to go active.				CR	RN	Sinker 325 19000. K
	CIC	Permission granted.					CR	RAR.
	CIC	Prep bloodhound prep torpedo countermeasures.					RN	Investigating our sinker with L2. K
	UB	Aye.					CR	RAR.
UB	CIC	L2 has radar contact BNG 250 RNG 18000. He has gone sinker.				AX	RN	Request datum designation our sinker BNG 200 10 miles Time 1301 datum error 1000 yds possub low, K
							AX	Roger designate datum A1, AR
						CR/ RN	AX	Signals AS18-3 desig datum A1 BT AS18-2 C/S RN K.
							RN	RAR.
	SON	Active sonar contact 325.				CR	RN	C015-1 desig CR. K
SON	CIC	Sonar evaluate that as CR.					CR	RAR.
						CR	RN	Execute Form Y starboard 230-50-25. K
CIC	UB	Have estimated position 235 17300 based on estimated course and speed of the target.					CR	RAR.
	CIC	Roger high speed leg cone of courses 063 15.				CR	RN	Cone of courses high speed leg 063 at 15 low speed leg 348 at 4 BT. Intend direct approach to datum. K
UB	CIC	ETA TDA 10.					CR	RAR.
						CR	RN	ETA at TDA is 1330. K
	UB	Passive sonar contact 018.					CR	RAR.

TABLE J-2. COMMUNICATIONS IN SHIP 1 - ABOVE AVERAGE PERFORMANCE - continued

SHIP 1

1JS			61JS			SAU REPORTING		
TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS
	CIC	Say again your passive sonar contact.						
BR	UB	Roger 018.						
		(Background: dipper is not there)						
UB	CIC	We marked the datum from us 240 17700.				CR	RN	Scene of action commander is RN. Weapons free possub confidence high or higher weapons tight if A/C in the area. K
	UB	Roger I have an estimated position 234.						
							CR	RAR.
CIC	UB	Estimated position 232 15500.				CR	RN	IHI corpen J 240 ISA corpen J 240 stby X. K
BR	CIC	Come left 240.						
							CR	RAR.
	BR	Steady 240.						
							RN	Intend intercept approach to datum. K
						CR	RN	Plan Red 3AN 13AN. Plan Black is 3S. K
							CR	RAR.
							RN	Reclassify datum A1 possub high. K
UB	CIC	Have madman with L2 BNG from us 243 15600				CR	RN	Have MAD contact from L2 BNG 243 156 conducting attack at this time K
	UB	Aye.					CR	RAR.
BR	CIC	Come left 230				CR	RN	Prep torpedo countermeasure. K
							CR	RAR.
CIC	UB	I say based on the BNG he going more northerly than we guessed, should be on course of about 030 040.				CR	RN	XTF turn Z desig K is 230-K SP 16-[illegible]. K
							CR	RAR.

TABLE J-2. COMMUNICATIONS IN *SHIP 1* - ABOVE AVERAGE PERFORMANCE - continued

SHIP 1

1JS			61JS			SAU REPORTING		
TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS
UB	CIC	Another madman 248 1446 L2 weapon away safe time 16.				AX	RN	Request BF turn to the northwest. K
							AX	Roger BF turning northwest. AR
CIC	UB	Concur I have 15.				CR	RN	L2 launch bloodhound away BRG 248 safe time 13.
						CR	RN	Prep 13AH sectors 3400 C/S CR 0006 C/S RN. K
UB	CIC	Looks like a course of about 340 350 from the MAD track					CR	RAR.
						RN	CR	Recommend 3402 for CR. K
UB	CIC	Dipper is hot he bears from us 246 13300. His contact 175 1850 BRG and RNG to follow, contact 246 13000 from us.					RN	I say again 3400 fo CR. K
							CR	Interrogative 20 degree sector for CR. K
CIC	UB	We still tracking 340.					RN	Correction sector 3000 C/S CR. K
	CIC	Looks like 022.					CR	RAR.
UB	CIC	Another madman 262 10900 L2 weapon away safe time 23.				CR	RN	N3 hot 175 1850 L2 madman 262 109. K
							CR	RAR.
	UB	That's a pretty radical jump I don't think he can make that.				CR	RN	N3 launch weapons. Weapons away BRG 130 safe time 1320. BT My goblin tracking 320 14. K
	CIC	Yeah I hold him 022 14 Kts.						
							CR	RAR.
BR	CIC	Come right 240.				CR	RN	INX corpen J 240 ISA Corpen J 240 stby X. K
UB	CIC	We have a madman 261 11400.				CR/ RM	AX	BF resuming base course at this time. AR
BR	CIC	Come right 260.				CR	RN	INX corpen J 260 ISA corpen J 260 stby X. K

TABLE J-2. COMMUNICATIONS IN SHIP 1 - ABOVE AVERAGE PERFORMANCE - continued

SHIP 1

1JS TO	1JS FM	1JS COMMUNICATIONS	61JS TO	61JS FM	61JS COMMUNICATIONS	SAU REPORTING TO	SAU REPORTING FM	SAU REPORTING COMMUNICATIONS
	BR	Aye 260.					CR	RAR.
CIC	UB	Hold us entering TDA at this time.				CR	RN	Hold us entering TDA at this time. AR
	CIC	Concur.					RN	IMX Turn Z desig 260 Xray K speed 16-22 stby X. K
BR	CIC	Standby we are executing Turn Z base course 260 high sp 22 low 16 time 22 we should be on 290.					CR	RAR.
	BR	My rudder is right coming to 290.					RN	My rudder is right corpen 290. K [CORPEN not needed, the plan designates the course]
SON	CIC	Run a sector search 220 to 300.					CR	Roger concur.
	SON	Say again.						
SON	CIC	Sector search arcs 220 to 300.						
	SON	Make that 240 to 300 it should be 60 degree arcs.						
	CIC	Roger 240 to 300 that's right.						
	BR	My rudder is right coming to 320.						
BR	CIC	Bridge next course will be 230.						
	BR	I have it figured up here (Background: he has a handle on it up there)						
UB	CIC	Do you have an estimated position on him?						
	UB	Roger 268 8500 should be coming into sonar range in a minute now.						

TABLE J-2. COMMUNICATIONS IN SHIP 1 - ABOVE AVERAGE PERFORMANCE - continued

SHIP 1

1JS			61JS			SAU REPORTING		
TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS
	CIC	ASAC is holding about the same.						
UB	CIC	We have a weapon in the water.						
	UB	Roger safe time 27.						
	CIC BR	Water entry point 292 9800. My rudder is left coming to 230.						
SON	UB	Have you completed those search arcs?				CR	RN	L2 bloodhound away safe time 1327. K
	SON	Negative.					CR	RAR.
UB	SON	Finished the search arcs no echos.						
SON	UB	Repeat the same search arcs. (Background: Good call)				CR	RN	My datum &2 BNG 268 9600 time 1322 datum error 10 source L2 MAD, K
CIC	UB	Estimated position 272 6800.				CR	RN	Contact estimated position 272 6800 from RN. K
BR	BR	My rudder is left coming to 200.					CR	RAR.
				SON	Contact 063 on oscellogram evaluated as BF.			
UB	CIC	Dipper is hot standby for, mark					RN	H3 hot BNG 165 1850.
UB	CIC	Prep bassett starboard.				CR	RN	X plan Red, sectors 3000 C/S CR 0006 C/S RN. K
CIC	UB	What's your BRG and RNG from us?					CR	RAR.
	CIC	273 19000.				CR	RN	My rudder is right my corpen 300. K
BR	CIC	Come starboard 300.					CR	RAR.

TABLE J-2. COMMUNICATIONS IN SHIP 1 - ABOVE AVERAGE PERFORMANCE - continued

SHIP 1

1JS			61JS			SAU REPORTING		
TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS
UB	CIC	Prep that bassett to port.						
	UB	Roger combat you had better come more starboard than that, about 320.						
	CIC	Roger 320.						
UB	CIC	Discontinue zig-zag plan continue 320 sp 27.						
UB	CIC	Madman 282 8200.						
UB	CIC	Do you have a good solution?						
	UB	Negative I don't hold contact I must fire manually.						
UB	CIC	Madman 282 7800.				RN	CR	Lance contact 242-63. AR
						CR	RN	Scraming L2 N3 to the north. Assume brother if you are hot. K
CIC	SON	I have active sonar contact 291 7250.		SON	Active sonar contact BRG 291 7260.		CR	Roger I am brother. K
				SON	Contact BRG 291 7170.		RN	RAR.
	BR	Steady 27 Kts.				RN	CR	Prep basset port intended firing BRG 238. K
UB	CIC	Go to scanner.					RN	RAR.
CIC	UB	Better get the speed down it's too high.				AX	RN	Request you turn BF northwest. K
BR	CIC	Slow to 20 Kts.				RN	CR	Bassett away water entry point 236-47 ANS. Safe time 1335. K
							RN	RAR.
CIC	UB	Suggest you come right 340.				RN	AX	BF rudder is right coming to new course 345. AR

TABLE J-2. COMMUNICATIONS IN SHIP 1 - ABOVE AVERAGE PERFORMANCE - continued

SHIP 1

1JS

TO	FM	COMMUNICATIONS
	CIC	Roger.
BR	CIC	Come right 340.
UB	SON	Active sonar contact 287 6600.
	UB	I have a green board except for permission to fire.
	CIC	Standby UB.
UB	CIC	UB conduct your attack.
	UB	Aye Green board 1 standby green board 2 weapon away firing BRG 291 range 6708. No apparent casualties.
	BR	Steady 340.
CIC	UB	We still have the contact tracking 022.

61JS

TO	FM	COMMUNICATIONS
	SON	Contact on the oscellogram 287
	SON	Active sonar contact 287 6640.
	SON	Contact BRG 287 6720.
	SON	Estimated course 210 Contact BRG 286 6660.

SAU REPORTING

TO	FM	COMMUNICATIONS
CR	RN	Evaluate your shot a hit. K
	CR	Roger concur. BT My latest 235-43 ANS. AR
CR	RN	My rudder is right course 340. K
CR	RN	Prep bassett 240. K
	CR	RAR.
CR	RN	Standby 280. K
	CR	RAR.
CR	RN	Basset away 291-67. K [RN should have assumed the duties of attacking ship before making the attack]
	CR	RAR.
CR	RN	Safe time 1327. K
	CR	RAR.

END OF PROBLEM

AVERAGE COMMUNICATIONS - SHIP 2

The transcription in Table J-3 reveals that the CIC in Ship 2 did not support UB and Sonar with all the information they had. The evaluator appeared to want all the known information about the submarine for himself and did not want to share it with UB and Sonar.

Example 1:

From CR to DR: "Lance contact BNG 262-71."

This report from the assist ship never reached UB or Sonar. This information should have been conveyed to all stations to assist them in gaining contact.

Example 2:

From DR to CR: "I have MAD. I have dipper. Revise possub classification high."

The reclassification was fine but the position of the submarine was not reported to the assist ship or to UB and Sonar. The assist ship could not correlate this contact to its own, and Sonar did not know where to concentrate the sonar search.

Example 3:

From SON to CIC: "Request search arcs."

From CIC to SON: "Negative at this time."

The evaluator in this case had the best information available and should have automatically assigned new search arcs.

TABLE J-3. COMMUNICATIONS IN SHIP 2 - AVERAGE PERFORMANCE
(Analyst's comments in brackets. See list of abbreviations in Table J-1)

SHIP 2

1JS			61JS			SAU REPORTING		
TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS
CIC	UB	Send all hostile reports. [Not needed]						
UB	CIC	Received LAMPS report. Will send true BNG and RNG when we get it.						
CIC	UB	You got the RNG & BNG yet?						
	CIC	Not yet.				AX	DR	Datum undesignated 341-12 time 1102 error 10 Source LAMPS sinker classified possub low. K
UB	CIC	Sinker 341 24000.					AX	Roger designate your datum A1. AR
						CR/ DR	AX	Signals AS19-3 desig datum A1-AS18-2 C/S DR. K
							DR	RAR.
							CR	RAR.
						CR	DR	C014-1 desig CR. K
							CR	RAR.
						CR	DR	XTF Form Y port 330-50-SP 27 Datum A1 341-12 time 1102 error 10 source LAMPS sinker classify possub low. K
							CR	RAR.
						CR	DR	Prep torpedo countermeasures BT XTF turn Z desig Xray 330 - K SP 16-22. K
							CR	RAR.

TABLE J-3. COMMUNICATIONS IN SHIP 2 - AVERAGE PERFORMANCE - continued

SHIP 2

1JS			61JS			SAU REPORTING		
TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS
CIC	SON	Verification of contact approx-imate BRG 255 7000 yds.				CR	DR	Prep plan 13A sectors 1016 C/S DR 1622 C/S CR. K [Why this before plane signal?]
	CIC	That's CR.					CR	RAR.
CIC	SON	Can you give me the BRG & RNG to BF?				CR	DR	Plan Red 3A-13A Plan Black 1S-3S weapons free possub high or higher Bassetts tight IF A/C in firing area. K
	CIC	BF 190 6000.					CR	RAR.
	CIC	Bridge combat [double call not needed]				CR	DR	Intend intercept approach to datum. AR
	BR	Bridge aye [double call not needed]				AX	DR	Revise datum A1 260-1u time 1105 error 10 source lamps sinker. Classify possub low. K
BR	CIC	Come to course 140 SP 27					AX	RAR.
UB	CIC	Revise datum 260 18000.				CR	DR	IMX Corpen J 260 ISA IMY Corpen J 260 stby X. K
BR	UB	What's our course?					CR	RAR.
BR	CIC	Come to new course 280.						
	BR	280 aye.				CR	DR	Latest position 270-18000 yds [From what or whom?]
							CR	RAR.
CIC	SON	What's the datum?						
	CIC	Datum 272 9400.				AX	DR	Revise datum A1 272-5 Time 1111 error 10 source LAMPS sinker classify possub low [should report why A1 revised two, dipper or sonar]
CIC	SON	Just a reminder, sonar has too much noise at 27 Kts to pick up anything.						

TABLE J-3. COMMUNICATIONS IN SHIP 2 - AVERAGE PERFORMANCE - continued

SHIP 2

1JS			61JS			SAU REPORTING		
TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS
CIC	UB	If th. sub was coming at us at 15 Kts it would be well within 7000 yds now.						
CIC	UB	The sub may have gone ceep.						
BR	CIC	Come to 15 Kts.						
	BR	Roger 16 Kts.						
	UB	Bloodhound preped port.		SON	Sonar has a contact off the port beam 4000 yds, classify as possub.	CR	DR	New sectors 0309 C/S DR 3916 C/S CR 9T X plan Black 35. K
	SON	Verification of contact 165 4000 yds.		CIC	Aye.			
	SON	Sonar contact 235 4900. Classify possub. Sonar holds up doppler bow aspect.		CIC	Believe that contact is CR.		CR	RAR.
				SON	Aye.			
SON	CIC	The assist ship is in that area.						
CIC	SON	Evaluated as assist ship.					DR	Request status of your contact. K
BR	CIC	Come left new course 180.					CR	I am cold at this time. AR
	BR	Roger 180.						
CIC	UB	Is anybody hot?				AX	DR	Recommend BF turn east at this time. K
	CIC	Negative					AX	RAR.
							CR	Lance contact BNG 262-71. K
							DR	RAR.
							CR	My latest 264-68. K
							DR	RAR.

TABLE J-3. COMMUNICATIONS IN SHIP 2 - AVERAGE PERFORMANCE - continued

SHIP 2

1JS			61JS			SAU REPORTING		
TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS
						DR	CR	Interrogative attack plan. K [CR should have X and assumed duties as attack ship]
						CR	DR	X plan Red, new sectors 0006 C/S DR 0610 C/S CR. K
							CR	Roger. BT my latest 268-58. K
							DR	RAR.
						DR	CR	My latest 278-57. K
						AX	DR	Revise datum A1 latest contact 278 5700. K
							AX	RAR.
						DR	CR	My latest 283-57. K
						CR	DR	I have MAD I have dipper revise possub classification as high. K
					[ASWOC Should have been reporting the MADs and dipper contacts to all stations]		DR	Revised classification of A1 is possub high I have dipper contact. K
BR	CIC	Come right to new course 250.					AX	RAR.
BR	CIC	Come right to new course 270.				CR	DR	Contact is tracking 082 at high speed. AR (send speed)
BR	CIC	Continue right to 200. ["To should not be used, it may be mistaken for 2]						
	SON	Sonar contact port bow 258 6850 classify possub.		SON	Sonar has contact off the port bow RNG 6500 classify as possub.	CR	DR	Lance contact 258-6500. K
						CR	DR	Roger my latest 299-52. AR

TABLE J-3. COMMUNICATIONS IN SHIP 2 - AVERAGE PERFORMANCE - continued

SHIP 2

1JS			61JS			SAU REPORTING		
TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS
BR	CIC	Come right 320.		CIC	Aye.	DR	CR	Mr corpen is right coming to 28[illegible]. K [Poor signal either my rudder is right or M Corpen is]
	SON	Contact has up doppler.						
CIC	SON	Contacts on the port beam.					DR	RAR.
	CIC	You still hot? [Should never have to ask]						
	SON	Contact 250 5800.						
CIC	UB	Request permission to fire.				DR	CR	My latest 127-46. AR
	CIC	Negative negative LAMPS helo in the area.						
CIC	UB	Hold the contact on course 050 SP 6 Kts. [CIC should have made comparison]						
	CIC	Very well.						
	UB	Contact has marked up doppler bow aspect.		SON	Contact has apparent bow aspect 252 5800.			
CIC	UB	Contact appears to be increasing speed.				DR	CR	My latest 312-44. AR
BR	CIC	Come right 000						
CIC	SON	If you come to 000 that will bring him to our port quarter pretty close to the baffles.						
	CIC	We realize. [More exchange needed here to ensure contact is held]						
CIC	UB	We have target in port turn.						
BR	CIC	Come left 310.		CIC	What's the BRG from us?			
	BR	Left 310 roger.		SON	BRG 252 5800.			

TABLE J-3. COMMUNICATIONS IN SHIP 2 - AVERAGE PERFORMANCE - continued

SHIP 2

1JS			61JS			SAU REPORTING		
TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS
				SON	Contact BNG 249 RNG 5100.			
				SON	Contact BRG 247 RNG 4800.			
				CIC	Can I have the latest mark on our contact?	DR	CR	I am cold my last 316-43. AR
				SON	BNG 245 RNG 4600. [Should never have to ask! Sonar should have kept on reporting the contact automatically]	CR	DR	My latest 245-46. AR [Good report]
						DR	AX	BF resuming base course at this time. AR
	SON	Sonar has no echos last BNG 245 RNG 4550.		SON	Sonar has no echos last BNG 245 RNG 4500.	CR	DR	I am cold, last contact 245 4550.
CIC	SON	We have a contact 196. Is that the assist ship?		SON	Sonar lost contact. Resuming beam to beam search.	CR	DR CR	X plan Black 3S. K RAR.
	CIC	That is the assist ship.						
CIC	SON	Request search arcs.						
SON	CIC	Negative at this time [Search arcs should have been given]						
CIC	UB	We have a bloodhound prepped to port.						
	CIC	Very well.						
CIC	SON	Lost contact we have completed our fixed review search arcs. Request new search arcs.						
	CIC	Request you search area from 210 to 270. [Transmission, "search arcs 210 270" would have been clearer and faster]				CR	DR	New sectors 3404 C/S DR 0410 C/S CR. K
							CR	RAR.

TABLE J-3. COMMUNICATIONS IN SHIP 2 - AVERAGE PERFORMANCE - continued

SHIP 2								
1JS			61JS			SAU REPORTING		
TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS
BR	CIC	Come to new course 340.						
	BR	340 Aye.						
CIC	SON	We have completed search arcs, no echos.		SON	Sonar has completed search arcs. No echos.			
	CIC	Aye.						
BR	CIC	Bridge combat. [Double call up here caused interruption]						
	SON	Sonar contact off port beam 228 RNG 3050, classify possub.		SON	Sonar has sonar contact port beam 228 3000, classify possub.	CR	DR	Lance contact 228-30. K
							CR	Roger BT. I am hot my goblin. BRG 310-23.
BR	CIC	Come to course 270.						
UB	CIC	Prep bloodhound port [Already reported preped]		SON	Contact BRG 221 2800.	CR	DR	Prep bloodhound por' X plan Red 13A. K
				SON	Contact has apparent bow aspect.			
CIC	UB	Bloodhound preped. Request permission to conduct urgent attack.					CR	RAR.
				SON	BRG 215 RNG 2800.			[Confusion here 13A should be standoff - should have X 3A]
				SON	Contact BRG 212 RNG 2700.			
	CIC	Say again. [Lost time because of lack of attention]		SON	Contact BRG 209 RNG 2600.			
	UB	Request permission to conduct urgent attack.			[Contact reports should be sent to assist ship at least every minute]			
	CIC	Permission granted. [This could cause trouble if the following is not granted]						
BR	CIC	Request permission to fire torpedo to port.						
	BR	Permission granted. Ship's procedure is awkward but not improper]						

TABLE J-3. COMMUNICATIONS IN SHIP 2 - AVERAGE PERFORMANCE - continued

SHIP 2								
		1JS			E1JS			SAU REPORTING
TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS
AS	CIC	Stand by.						
AS	CIC	Shoot.						
BR	CIC	Come right new course 000.						
CIC	SON	000 will put the contact in or near the baffles. [Good call]						
	CIC	That's right, we are going to continue around. CR is hot. We are going to let him make an attack.						
		[If the plan was to drag the contact through the baffles, sonar should have been notified in advance. Also, UB and Sonar should be notified when the assist ship is hot]						
CR	UB	We fired a torpedo off the port side with a 70 degree gyro angle				DR	CR	Lance contact 310-25. K
							DR	RAR. [Believe bloodhound fired on BNG 225 by DR. Both units talking at the same time]
						DR	CR	My latest 306-18. AR
		[This should not be an after the fact report but when it happens and the BNG included]			END OF PROBLEM			

POOR COMMUNICATIONS - SHIP 3

The transcription in Table J-4 shows that in ship 3, CIC and UB appeared at times to be competing with each other rather than operating as a team. UB attempted to give the submarine position to CIC, but CIC made no attempt to verify or correlate the position and report to UB. This team interrupted crucial reports, talked at the same time, and in general did not communicate effectively with each other. This resulted in mission failure.

Example 1:

From UB to CIC: "Is the aircraft hot?"

From CIC to UB: "Yes we have an approximate course on the submarine."

When the submarine's position, course, or speed is known, all stations and ASW units should be notified automatically. This allows everyone to concentrate on that position and to set up a dead reckoning track.

Example 2:

From UB to CIC: "Target's course and speed?"

CIC had received the course and speed from the assist ship, but did not respond to this request from UB.

Example 3:

From SON to CIC: "Sonar contact..."

This most critical report was interrupted by CIC.

Example 4:

From CIC to BR: "Bridge combat bridge combat turn..."

This transmission was also interrupted. Sonar was attempting to report a sonar contact when CIC interrupted them to make a maneuver and UB interrupted CIC to report a plotter malfunction. This entire series of communications was unsatisfactory and showed poor team behavior.

Example 5:

From UB to CIC: "I am going to put a bloodhound in the water."

From SON: "Classification possible torpedo."

From UB to All Stations: "Standby."

From CIC: "OK; wait wait."

From UB to CIC: "Firing bearing 180."

This was another series of unsatisfactory communications. First the evaluator in CIC should order weapons fired, not UB. The stage was set for this earlier when UB was allowed to prep a weapon without being ordered to do so, and the evaluator lost control. Next UB, Sonar, and CIC were only getting bits and pieces of information out, not full reports. Finally, the evaluator in CIC had a habit of beginning each transmission with "O.K." Therefore, when UB gave the "Standby," CIC said, "O.K.," which UB took as permission to fire. As soon as CIC said "O.K.," UB fired. What CIC was attempting to say was "wait," but it came too late.

The external communications for Ship 3 were not good either. Because of the overall poor performance, they never really had a contact to report. The first error made was early in the exercise when the sinker was first reported.

Example 6:

From LY to CR: "Datum A1 260-12 time 0902 Source L2, classify possub high."

L2 is the LAMPS helicopter and was the only one to report a radar sinker. This is not enough for a classification of possub high.

Example 7:

From LY to CR: "H3 weapon away safe time 0922 water entry point will follow."

This report was correct, but it was the first indication that the Dipping Helo was in contact, and even this was not reported internally.

TABLE J-8. COMMUNICATIONS IN SHIP 3 - BELOW AVERAGE PERFORMANCE
(Analyst's comments in brackets. See list of abbreviations in Table J-1)

SHIP 3

USS			SIJS			SAU REPORTING		
TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS
AS	CIC	Radar contact from L2 information to follow.						
	UB	Request permission to set ASROC white.				AX	LT	L2 has radar contact on sinker BRG 260 24000 LT. K
							AX	Designate your datum A1. AR
						LT/GR	AX	Signals AS19-3 desig datum
A1 - AS18-2 C/S LT. K								
	CIC	Permission granted.					LT	RAR.
AS	UB	Set ASROC white.				CR	LT	CO 15-1 desig C/S CR. K
AS	CIC	Sonar has set ASROC white, conducting standard beam to beam search.					CR	RAR.
						CR	LT	Datum A1 260-12 time 0902 source L2, classify possub high. K
CIC	UB	Bearing and range to datum please. [CIC should have automatically reported datum as soon as it was known]					CR	RAR.
UB	CIC	Surface contact gone sinker 260 24000.						
UB	CIC	High speed leg 080 15.				CR	LT	Cone of courses high speed leg 060 15 low speed leg 030 7. K
	UB	Aye.					CR	Roger concur. AR
		[Background: That can't be right, the contacts BRG 260. That course won't get him there. Ask CIC to verify.)				CR	LT	Radar contact BRG 260 23500. K
							CR	RAR.
							LT	Plan Red 3A 13A plan Black is 3S BT SAC is LT. K
CIC	UB	PK 23600 BRG 260 bloodhound preped to port.						

TABLE J-4. COMMUNICATIONS IN SHIP 3 - BELOW AVERAGE PERFORMANCE - continued

SHIP 3

1JS			61JS			SAN REPORTING		
TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS
							CR	RAR.
						CR	LY	XTP Form Y port 280-55 SP 27. K
							CR	RAR.
	SON	Sonar contact 247 5100 believe it's CR.	CIC	SON	Possible sonar contact 320.	CR	LY	XTP Turn X desig Xray 280-K SP 16-22. K
							CR	RAR.
	CIC	That's CR.		CIC	Say again.			
CIC	WB	Verify the high speed leg		SON	It was a non sub.	CR	LY	ETA at TDA 0913. K
BR	CIC	Indicate turns for 27 Kts.						
	ER	Aye 27 Kts.		CIC	Roger the assist ship I think.		CR	Roger do not concur. AK
AS	CIC	Revise TDA time 18. [The original time was never sent]		SON	Yeah it was obvious.	CR	LY	ETA at TDA 0918. K
CIC	WB	Verify cone of courses. [This is the second request to verify cone of courses, CIC fail to respond]					CR	Roger, concur. AR
BR	CIC	Left standard rudder steady 280 Form Y base course 280 sp 27. CR is off the port side 5000 yds. [CR's position should have been directed to WB and SON]						
	BR	Aye 280.						
CR	SON	Do I understand you have increased ownship speed to 27?						
	CIC	Who is the calling station?						
	SON	Sonar.						

TABLE J-4. COMMUNICATIONS IN SHIP 3 - BELOW AVERAGE PERFORMANCE - continued

SHIP 3								
1JS			61JS			SAU REPORTING		
TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS
	CIC	Yeah, that's right 27 Kts.						
BR	CIC	Increase rudder to left full steady 280.						
CIC	UB	PK 20800 BRG 250						
CIC	UB	Is the A/C hot? [When the A/C became hot, SOH and UB should have been notified of the position]						
	CIC	Yes we have an approximate course on the submarine. [AS and the A/S should have been notified of the course]						
AS	CIC	Datum 250 18000.						
	UB	Say again.						
	CIC	Wait OK datum 250 2150. [CIC's habit of beginning transmissions with OK will be a problem later]						
	UB	Do you have a course and speed on the target?						
	CIC	Negative.				CR	LY	Weapons free classification possub high or higher Bassetts tight if A/C in the firing area. K
LB	CIC	Search arcs 260 280 [Search arcs should be 60 degrees]						
	UB	PK 15800 243.					CR	RAR.
	CIC	Search arcs 230 2700 [Should be 60 degrees]				CR	LY	Prep torpedo countermeasures, K
CIC	SOH	We have completed first search arcs 260-280 no apparent echos.					CR	RAR.

TABLE J-4. COMMUNICATIONS IN SHIP 3 - BELOW AVERAGE PERFORMANCE - continued

SHIP 3

1JS			61JS			SAU REPORTING		
TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS
	CIC	OK continue 260-280 [Should be 60 degrees]				CR	LY	M3 weapon away safe time 0922 water entry point will follow. K [This was the first indication M3 had a contact]
							CR	RAR.
							LY	Prep plan 13A sectors 0206 C/S LY 0610 C/S CR. K
							CR	RAR.
							LY	Water entry point 250 15000 firing BRG 090. K
AS	CIC	M3 has a weapon in the water firing BRG 105. [UB and Sonar should be notified where the Helo's contact is]						
CIC	SON	Search area 230-270 completed no apparent echos.				CR	LY	Correction firing BRG M3 weapon 105. K
							CR	RAR.
BR	CIC	Execute Turn X base course 280 I need course & speed.				CR	LY	Turn X desig Xray stby X. K
							CR	RAR.
CIC	BR	Time 19 course 340 sp 16.				CR	LY	M corpen 340 M speed 22. K
BR	CIC	Come to 340 sp 22.					CR	RAR.
CIC	UB	FK 11750 BRG 225.						
CIC	BR	Recommend course change at time 22.						
BR	CIC	OK come to 250 sp 22.						
CIC	UB	Be advised on our plotter we are not displaying ownship.						
	CIC	OK we hold the contact on approximate course 100 sp 12.						

TABLE J-4. COMMUNICATIONS IN SHIP 3 - BELOW AVERAGE PERFORMANCE - continued

SHIP 3

1JS			61JS			CAU REPORTING		
TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS
AS	CIC	CR is hot. [Should have reported the] position of CR's contact]						
AS	SON	Sonar contact 179 4470.	AS	SON	Sonar contact 179 4900.			
	CIC	OK that's CR. Classify that as non sub.		CIC	That's the assist ship don't fire on that.			
	BR	Time 25 course 250 high speed 22 Kts.		SON	Are you sure about that?			
CIC	UB	Request datum. [Should have been reporting CR's contact all along]		CIC	Yes.			
	CIC	OK CRs hot 205 68 from us.		SON	Where do you have the assist ship now?	LT	CR	Lance contact BRG 261-69. K
CIC	UB	Target's course and speed. [CIC failed to advise UB of the contact's course and speed, which was received from CR]		CIC	CR bears 155 BF BRG 128.		LT	RAR.
						LT	CR	My latest 259-66. AR
						LT	CR	My latest 255-63 hold contact tracking 060 indicating 15. AR
						LT	CR	My latest 253-59 ANS. AR
						CR	LT	Madman BRG 226 9400 LT. K
							CR	RAR.
						LT	CR	My latest 2[illegible] 56 ANS. AR
	CIC	OK search arcs 180-220.				LT	CR	My latest 249 54. AR
						LT	CR	My latest 247 51. AR
	UB	CIC, come back one more time. [A simple repeat would have been better]				LT	CR	My latest 245 49. K [LT fail to acknowledge]
	CIC	Search arcs 180-220.				LT	CR	My latest 243 47. AR

TABLE J-4. COMMUNICATIONS IN SHIP 3 - BELOW AVERAGE PERFORMANCE - continued

SHIP 3

1JS			61JS			SAU REPORTING		
TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS
	UB	Copy 180 220.						
CIC	BR	Time 27 course 280 sp 16.						
						LY	CR	My latest 240 44 ANS BT contact update tracking approximate course 245 at medium speed.
CIC	BR	Do you plan to follow the zig zag plan? [CIC is obviously not keeping AS informed]						
	SON	Sonar contact [interrupted by CIC]						
							LY	RAR.
BR	CIC	Bridge combat bridge combat turn [interrupted by UB]						
		[These two transmissions indicate very poor procedue and lack of team work]						
						LY	CR	My latest 236 42. AR
CIC	UB	We have plotter malfunction we are going to have to shoot manually.						
						AX	LY	Request BF turn starboard 020. K
							AX	RAR.
	CIC	OK.						
						LY	CR	My latest 230 37 ANS. AR
	SON	Sonar has hydrophone effects 198.		SON	Hydrophone effects wait a minute.	LY	CR	Hold contact in a port turn. K
							LY	RAR.
	CIC	Increase sp 27 Kts.			[The uncertainty of such a critical report shows a level of inexperience]			
	SON	Belay that. [All stations talking at once]						
	CIC	Increase speed 27 Kts.						
AS	SON	Sonar does have hydrophone effects BNG 198. [Interrupted by UB]		SON	Hydrophone effects BNG 195 BNG 3395 classified as torpedo.			
CIC	UB	I'm going to put a bloodhound in the water.						

TABLE J-8. COMMUNICATIONS IN SHIP 3 - BELOW AVERAGE PERFORMANCE - continued

SHIP 3

1JS			61JS			SAT REPORTING		
TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS	TO	FM	COMMUNICATIONS
	SON	Classification possible torpedo.						
AS	UB	Standby.						
	CIC	OK. wait wait.						
CIC	UB	Firing bearing 180.		SON	Firing bearing 180.	CR	LT	Bloodhound away to port firing bearing 200. K [Reported wrong firing beam]
UB	CIC	Before you make a shot let me know what you are doing, you are firing without telling [illegible]			(Background: Sonar never told me they were hot.		CR	Roger Stop the problem
CIC	UB	I let you know [illegible] was going to fire a bloodhound on the bearing of the hydrophone effects.			Instructor: They were hot for about 10 pings!			
		(Unidentified station had a discussion with evaluator about countering an incoming torpedo with a bloodhound)						
UB	CIC	Come up to problem control we'll talk about it.						
		(Background: From sonar I was trying to put out a sonar contact. He (CIC) broke in with the bridge and wouldn't let me put it out saying "I have more [expletive deleted] important things than a [expletive deleted] sonar contact." [This was the interpretation the sonar operator put on the evaluators actions])						

END OF PROBLEM

QUALITY VS. QUANTITY OF TRANSMISSIONS

To summarize the analysis, it was found that the ship with the best exchange of necessary information did the best job. It is important here to stress the quality of the transmissions, not quantity. As demonstrated in Tables J-2, J-3, and J-4, each ship communicated with the other stations and units. These tables also point out that Ship 1 had an exchange of information, the evaluator (in CIC) relayed all contact information and intentions to UB and the assist ship. They also correlated their information to arrive at a decision on what the contact was doing and how best to counter the submarine. Ship 2, on the other hand, had mostly a one-way information flow, the evaluator received all the contact information but did not relay all of it to the other stations. In this case, the mission was successful, but the decision on the best course of action was made by one person, the evaluator. Ship 3 had communications but very little information flow, and the communication procedure was very poor. In Ship 3 no one took charge to coordinate the communication or anything else.

An analysis of the number of useful communications relative to the total number of communications was conducted to determine what effect the communication had. Table J-5 shows the tabulation of total number of transmissions on the SAU reporting and 1JS circuits along with the percentage of unnecessary transmissions.

TABLE J-5. PERCENTAGE OF UNNECESSARY TRANSMISSIONS.

	Ship 1		Ship 2		Ship 3	
	SAU Reporting	1JS	SAU Reporting	1JS	SAU Reporting	1JS
O/S Ship						
Number of Transmissions	41	88	27	83	21	77
% Unnecessary	4.8	7	11.9	37	24	45
A/S Ship						
Number of Transmissions	8		16		16	
% unnecessary	37.5		12.5		12.5	

SUGGESTIONS FOR COMMUNICATIONS CONTROL

Perhaps a training system that has the ability to control communication, offer prompts when a transmission is required, and correct or limit unnecessary transmissions is what is needed to strengthen overall team performance. Such a system would have at least two major advantages over existing systems. First, the team member would be placed into simulated actual situations where he would be trained in what he must communicate to the other stations and what he should expect to receive from the other stations. Secondly, because the team members normally identified for this training are senior personnel, they would not feel that their intelligence was being insulted by junior personnel correcting or telling them what must be transmitted.

In the following paragraphs, excerpts from the transcriptions are provided along with comments and suggested prompts.

SHIP 1:

Transmission:	"CR this is RN prep 13AH sectors 3400 C/S CR 0006 C/S RN."
Comments:	Four transmissions were used here to ascertain that CR's sector was only 20 degrees and should have been 60 degrees.
Prompt:	"Use standard 60 degree sectors."
Supposition:	Three unnecessary transmissions would have been eliminated. RN would have sent a correction to the original transmission assigning CR a 60 degree sector.

Transmission:	"CIC this is UB. Better get the speed down, it's too high."
Comment:	Even though this transmission was good on the part of UB, CIC should have ordered optimum sonar speed when they were within PSR.
Prompt:	"You should be at optimum speed. You are in TDA."
Supposition:	Sonar would have detected the contact sooner and would not have had to remind CIC that the speed was too high.

Transmission:	"CR this is RN. Prep Bassett 240."
Comment:	This could have led to a confusion between CR and RN. RN should have assumed the duties as attacking ship

and sent the transmission, "I am brother, prep Bassett 240."

Prompt: "Assume brother before you prep the weapons."

Supposition: The importance of switching of attacking ship and assist ship would be reinforced.

SHIP 2

Transmission: "CR this is DR. I have MAD. I have dipper. Revise possub classification as high."

Comment: With three sources holding the same contact, it could have been classified as a prop sub. UB and sonar were not notified of these contact reports. Sonar, UB, and the assist ship should have been notified and given the position for the MAD and dipper's contact.

Prompt: "Report all units contact position to all stations."

Supposition: The assist ship could correlate the position with her contact. UB and Sonar could concentrate the search in the contact area and after a series of such reports, establish their own plot and assist the evaluator with estimated positions until contact was made.

Transmissions: "BR this is CIC. Come right 000."

"CIC this is Sonar. If you come to 000 that will bring him to our port quarter pretty close to the baffles."

"CIC we realize."

Comment: This series of transmissions had many errors that could have proven disastrous. First, when the sonar operator realized the selected course would put the contact near the baffles, he should have recommended a better course. Second, when notified that such a course change would put the contact near the baffles, he should have changed course, realizing at this point he was the only one hot and not taken the chance of losing contact. Third, the evaluator did not advise UB and Sonar of his intentions beforehand, so they could make recommendations before the action was begun. 'ourth, if in this case the submarine

had turned starboard vice port, DR would have been in a dangerous position with the submarine astern of the ship.

Prompt: When the course change was ordered: "Have Sonar and UB been advised of your intentions?"

When the course change has been executed: "This course will put the ship in danger, recommend 340."

Prompt to Sonar when the warning is sent to the evaluator: "Send course recommendation and reason."

Supposition: If the evaluator gets in the habit of announcing his intentions, the chance of team decisions are better, and he can be warned of possible errors. If an error is made and he is notified at once that the ship is in danger, the chances are he will remember that the next time. Sonar should get in the habit of sending recommendations to aid the evaluator.

Transmissions: "CR this is DR. Lance contact 228-30."

"This is CR. Roger, I am hot. My BNG 310-23."

"CR this is DR. Prep bloodhound port execute plan Red 13A."

"CIC this is UB. Request permission to conduct urgent attack."

Comment: In this series of communications, tactical and procedural errors were made as well as errors of omission. It was a tactical error to execute plan 13A because of the range. Plan 3A should have been executed instead. The second tactical error was failure to order an input attack immediately when the contact was detected at such a close range. It should not have been necessary for UB to recommend it. The error of omission was the failure to designate the attacking ship. If both had conducted an urgent attack, it could have caused interference between the torpedoes.

The procedural error was the failure of CIC to recognize the request for an urgent attack. This allowed the submarine to close from 3000 yards to less than 2600 before shooting. This problem snowballed from errors made previously when UB had a good solution and requested

permission to shoot, which was denied because of the LAMPS helo. This was wrong for two reasons: first, the only weapon prepped was a bloodhound which would not affect the helicopter; secondly, if the evaluator was worried he should have ordered the LAMPS helicopter cleared and then given permission to fire.

Prompt: The initial prompt should have been, "A bloodhound shot will not endanger the LAMPS helo." The prompt for the existing situation should be, "Plan 3A is the preferred attack plan for this range. Recommend an urgent attack. Recommend you assume duties as brother."

Supposition: The submarine would have been attacked much earlier if the recommendation "a bloodhound shot will not endanger the helo," had been followed. If plan 3A was executed the SAU would have been in much better position to hold contact and make attacks, DR would have taken the north sector as brother and CR south as sister, and conducted an urgent attack to allow time for a good fire control solution.

SHIP 3:

Transmission: "CIC this is UB. PK 23600 BND 260 bloodhound prepped to port."

Comment: The initial part of this report was good, but the evaluator is the person that orders weapons prepped, not UB.

Prompt: To the evaluator, "Notify UB that you will designate which weapon is to be prepped and on which side."

Supposition: Control would be established now, which will eliminate problems that occur later.

Transmissions: "CIC this is UB. Is the aircraft hot?".

"This is CIC. Yes, we have an approximate course on the submarine."

Comment: Had CIC been doing their job as part of the ASW team, UB would have known the aircraft was hot and the contact's position each time it was reported. The assist ship did not receive a contact report either. The evaluator should have relayed all the information available to all

stations. Furthermore, merely knowing that CIC has a course on the submarine does not help UB and Sonar develop a plot and locate the contact.

Prompt: When the aircraft first reported a contact, "Disseminate contact report to all stations and ASW units."

Supposition: UB would have developed a lot and supplied the evaluator with estimated position and recommendation to bring the contact into detection range. Sonar would have concentrated the search in the area of the submarine and not been worried about the contact that was the assist ship. CR would have developed a plot and concentrated her search in the submarine's area.

Transmissions: "All stations this is Sonar, Sonar does have hydrophone effects BNG 198..."
[This transmission was interrupted by UB]

"CIC this is UB. I'm going to put a bloodhound in the water."
"This is sonar classification possible torpedo."

"All stations this is UB. Standby."

"This is CIC. O.K.; wait wait."

"CIC this is UB. Firing bearing 180."

Comment: This series of transmissions is an example of very poor communications control. Highlighted here are two definite procedural errors that were prevalent throughout this exercise. First, the interruption of transmissions is unsatisfactory. Stations having urgent traffic should use the standard break in procedures, "Silence on the line silence on the line." In this case, there are not many, if any, more urgent transmissions than a hydrophone effects report because it means that the submarine has most likely fired a torpedo at the ship.

The second procedural error that came into play was the evaluator's habit of starting transmissions with "O.K." In this dialog UB took the "O.K." as permission to fire, and before he said, "wait wait," the weapon was fired. These procedural errors combined with the lack of communication control, were the cause of the weapon being fired without actual permission being given. If control had been established as suggested in the

first error examined, UB would have recommended that a bloodhound be put in the water and would not have fired after the standby until told to do so.

Prompt: When UB attempted to break in, "Wait for Sonar to complete their report."

When UB announced that they were going to put a bloodhound in the water, "UB, this should be a recommendation."

When CIC replied, "Use standard terminology." [This habit should have been addressed long before this point.]

If UB announced they were going to put a weapon in the water, prompt to evaluator, "Send, 'standby, I have control' report to UB."

In summary, if communications as defined in the American College Dictionary, "the imparting or interchange of thought, opinions or information by speech, writing or signs" were strictly adhered to and all stations and units communicated with each other, the ASW problem would be limited to detection and final tactical decision based on all the known facts. A method to train teams to communicate effectively deserves the utmost attention.

APPENDIX K

GENERIC ASPECTS OF THE ASW PROBLEM

Much of the discussion in this report has focused on specific details of ASW CIC team behavior. Lest it be forgotten, however, that as the RFP points out, this study is aimed at "specifying the application of automated training technology for a variety of military teams in their respective team training environments," it is important to stand back from the details and observe that the scenario chosen involves just a specific example of a common military team consisting of a decision maker and highly skilled, crucial support members. This abstract problem situation has been given the flesh of an ASW problem to a) give the training device a measure of face validity, and b) ensure that team training issues relevant to military training are addressed. It is important to realize, however, that the system is being designed to deal with the generic rather than the specific training problem, and that the approach which has been described would be equally valid for application to the training of AAW teams, mine-hunting teams, and a variety of other military teams. The general guidelines could be adapted to fit many military team structures.

To validate this assertion, AAW team training was observed. These observations verified that the team members and their tasks match very closely. The ASW team selected for this study consisted of the ASWOC, ASAC, and the ASWFCO, representing a decision maker and two of the more critical skilled members. There is a direct comparison between these ASW team members and the Tactical Action Officer (TAO), Air Intercept Controller (AIC), and Ship's Weapons Coordinator (SWC) Anti-Air Warfare (AAW) team members, respectively.

In the ASW team, the ASWOC is required to make decisions, operate the OSC, issue directives as needed, take action as the situation dictates, and to communicate on the radiotelephone and sound powered telephone. In much the same way, the TAO is required to make decisions, operate the OSC (optional), issue directives as needed, take action as the situation dictates, and to communicate on the sound powered telephone and radiotelephone, if necessary.

With respect to the supporting team members, the ASW ASAC is required to control the helicopter, make decisions concerning the air control problem, lay buoy patterns, conduct MAD trapping searches, and control the helicopter during a MADVEC, keeping the ASWOC advised of the helicopter's actions. Similarly, the AAW AIC is required to control the CAP, make decisions concerning the air control problem, maintain the CAP on station, make intercepts on incoming raids, and conduct in-flight refueling rendezvous. He must also keep the SWC advised of the CAP's progress and actions.

In comparing the SWC and ASWFCO, some disparities were evident, but the SWC was required to do all that the ASWFCO did, except actually fire the weapon. The ASWFCO is required to direct the activities of the sonar operators, follow the orders of the ASWOC, assign search arcs, prepare and

fire the weapons, and keep sonar and the ASWOC advised of sonar conditions and search parameters. In AAW the SWC is required to direct the activities of the detector/trackers (through the Track Sup), follow orders from the TAO, assign long, medium, and short range radar searches, assign weapons to designated tracks, and order the weapons fired as directed by the TAO.

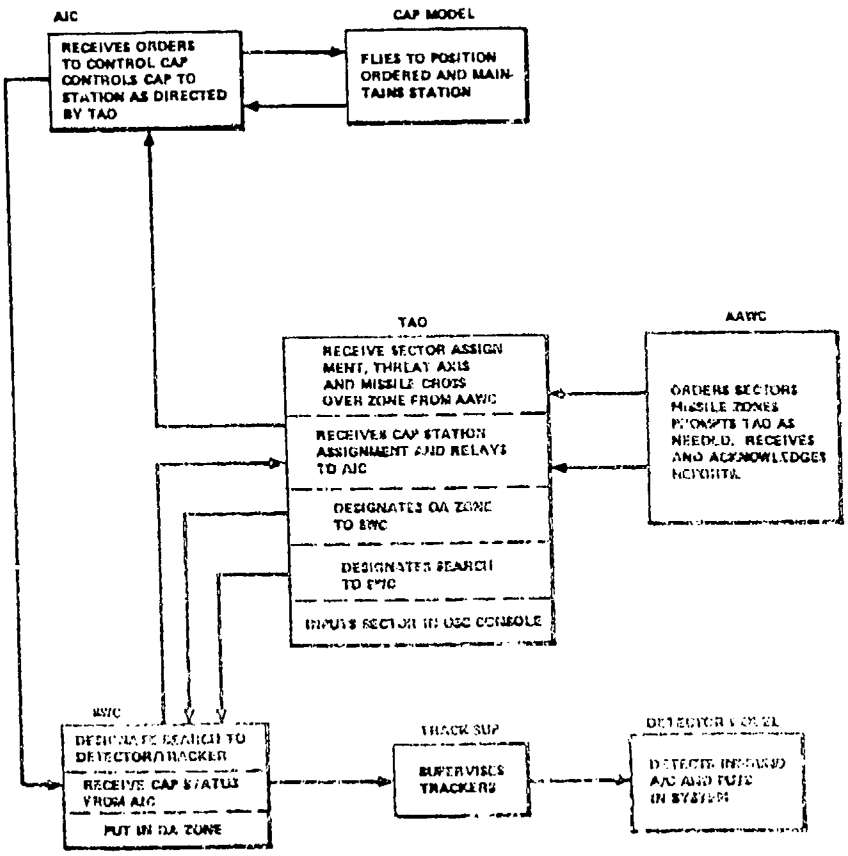
The other supporting team members provide the same types of input in both the ASW and AAW environments. Some jobs are combined, others are separated, and the names change, but the overall task remains very similar (e.g., the ASW sonar operator and the AAW detector/tracker are responsible for the detection and tracking of contacts in their respective environments, and for providing this information to the applicable team members).

To illustrate the generic nature of the ASW team training problem an action by action example of one small part of the AAW/ASW problems is shown in Table K-1. Figure K-1 provides a graphic representation of the information flow for this AAW scenario. Comparing this with Figure C-1 of Appendix C reveals that the communication requirements are likewise very similar to those of an ASW problem. The generic aspects common to both ASW and AAW problems are shown in Figure K-2.

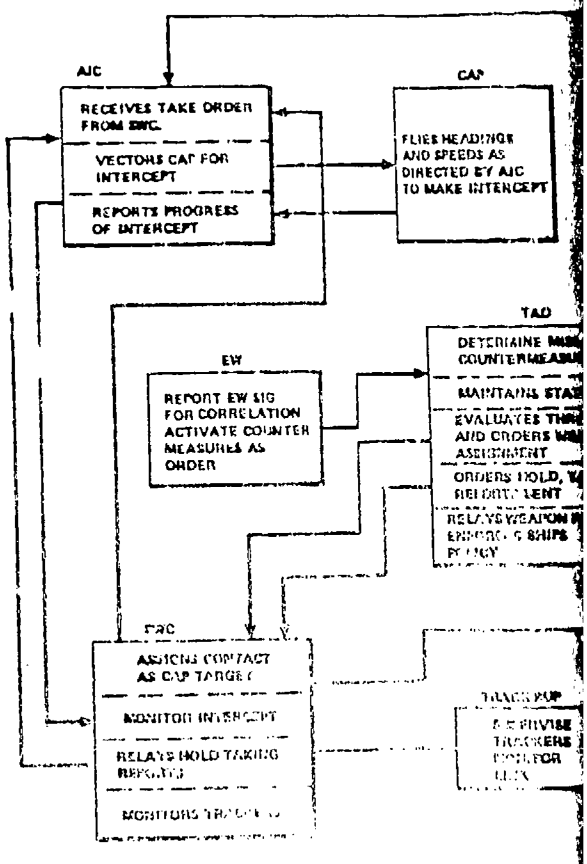
TABLE K-1. COMPARISON OF ASW PERSONNEL AND AAW PERSONNEL IN THE ATTACK PHASE.

Anti-Submarine Warfare	Anti-Air Warfare
SONAR reports a submarine contact. The report is both verbal and by console functions.	DETECTOR/TRACKER reports an air contact. This report is by console action only.
ASWOC verbally orders torpedo countermeasures.	TAO verbally designates missile countermeasures.
ASWOC designates weapon assignment to the ASWFCO. Designation is verbal and by console action.	TAO designates weapon assignment to SWC. Designation is verbal and by console action.
ASWFCO assigns weapon to the target and reports ready to the ASWOC.	SWC assigns weapon to the target and reports taking arget and weapon to all AAW units
ASWOC orders the helicopter cleared from the weapon area.	TAO orders the CAP cleared from the missile zone.
ASAC vectors the helicopter out of the area.	AIC vectors the CAP out of the area.
ASWOC maneuvers the ship into firing position.	TAO maneuvers the ship (if necessary) to clear the battery.
ASAC Reports when the helicopter is in a safe area.	AIC reports when the CAP is in a safe area.
ASWOC orders weapon fired.	TAO orders weapon fired.
ASWFCO reports weapon fired to the ASWOC.	SWC reports weapon fired and target to all AAW units.
ASWOC reports weapon fired, direction, and safe time to the SAU.	
ASWFCO relays sonar's evaluation of kill (e.g., breaking up noises, explosions, etc.) to the ASWOC.	SWC reports results of attack to all AAW units and the AAWC (e.g., splash one bomber heads up one bomber).

STEP 1


AIC
RECEIVES ORDERS TO CONTROL CAP CONTROLS CAP TO STATION AS DIRECTED BY TAO
CAP MODEL
FLIES TO POSITION ORDERED AND MAINTAINS STATION
TAO
RECEIVE SECTOR ASSIGNMENT, THREAT AXIS AND MISSILE CROSS OVER ZONE FROM AAWC
RECEIVES CAP STATION ASSIGNMENT AND RELAYS TO AIC
DESIGNATES OA ZONE TO SWC
AAWC
ORDERS SECTORS MISSILE ZONES PROMPTS TAO AS NEEDED. RECEIVES AND ACKNOWLEDGES REPORTS
RECEIVE CAP STATUS FROM AIC
PUT IN OA ZONE
TRACK SUP
SUPERVISES TRACKERS

STEP 2


AIC
RECEIVES TAKE ORDER FROM SWC
VECTORS CAP FOR INTERCEPT
REPORTS PROGRESS OF INTERCEPT
CAP
FLIES HEADINGS AND SPEEDS AS DIRECTED BY AIC TO MAKE INTERCEPT
TAO
EW
REPORT EW SIG FOR CORRELATION ACTIVATE COUNTER MEASURES AS ORDER
MONITOR INTERCEPT

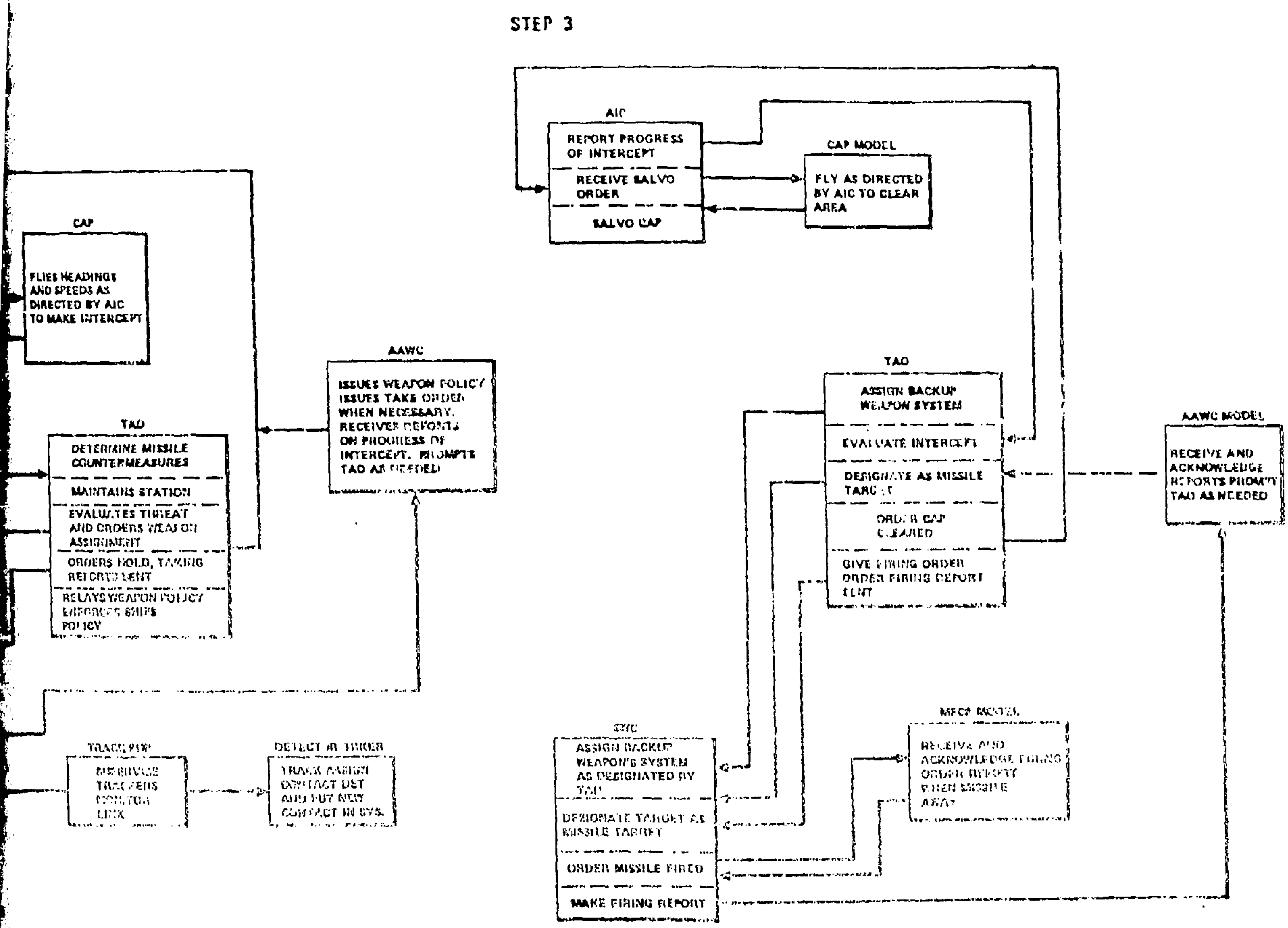


Figure K-1. Information Flow in an AAW Problem

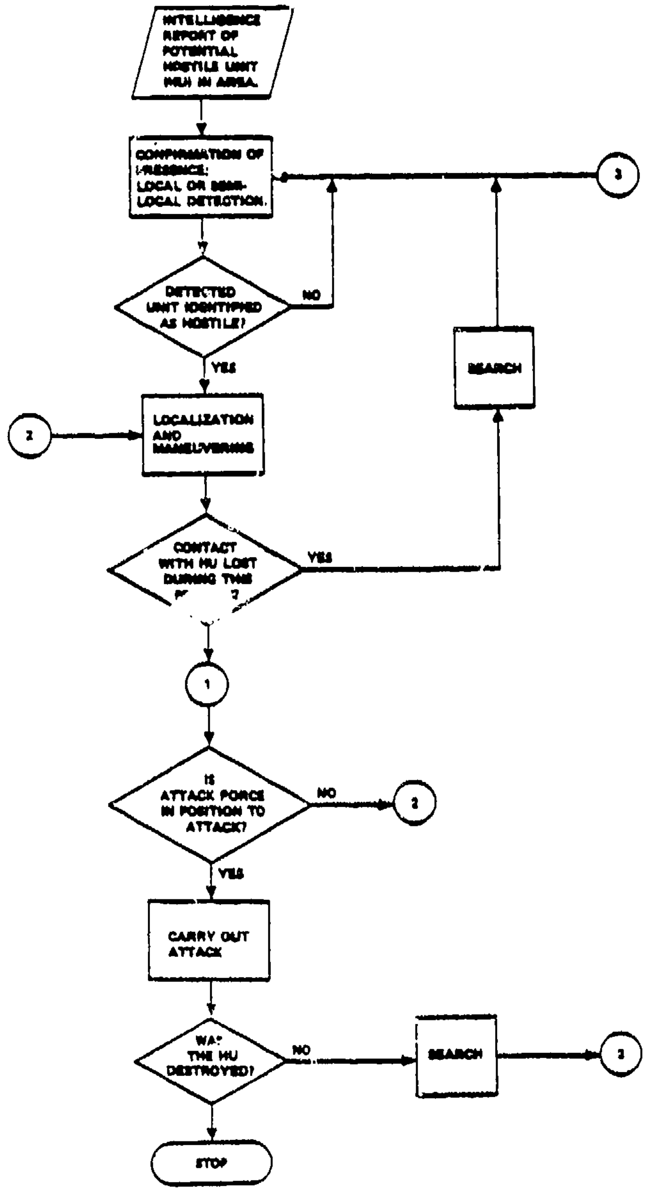


Figure K-2. Generic aspects of ASW and AAW problems.

GLOSSARY OF TERMS AN ACRONYMS

AAW	Anti-Air Warfare
AAWC	Anti-Air Warfare Commander
ACE	Air Controller Exerciser
ACU	Air Control Unit
AFTS	Automated Flight Training System
AIC	Air Intercept Controller
ASAC	Anti-Submarine Air Controller
Assist Ship	Other ship(s) of a SAU that may or may not have sonar contact, maneuvers to support the attack ship
ASW	Anti-Submarine Warfare
ASWFCO	Anti-Submarine Warfare Fire Control Officer
ASWOC	Anti-Submarine Warfare Operations Coordinator
Attack Ship	Ship that first gains sonar contact
CAI	Computer Aided Instruction
CAP	Combat Air Patrol
CIC	Combat Information Center
CRT	Cathode Ray Tube
Datum	Last known position of a submarine now lost
Dog Box	Area in which an active weapon can acquire a target; or, an ASROC explosion area
DEC	Digital Equipment Corporation
DRT	Dead-Reckoning Tracer
DD 963	Spruance class destroyer
ETA	Estimated Time of Arrival
FOC	Furthest On Circle, the furthest estimated distance the submarine can travel in a given time
GCA-CTS	Ground Controlled Approach Controller Training System
LAMPS	Light Air Multi-Purpose System
LPC	Linear Predictive Coding
MAD	Magnetic Anomaly Detector
MADVEC	Magnetic Anomaly Detector Vector
NEC	Nippon Electric Corporation
NTDS	Naval Tactical Data System
NAVTRAEQUIPCEN	Naval Training Equipment Center

GLOSSARY OF TERMS AND ACRONYMS, Continued

ODT	Omni Directional Transmission
OSC	Operations Summary Console
OSD	Operational Sequence Diagram
OTC	Officer in Tactical Command
PAR	Precision Approach Radar
PDT	Preformed Directional Transmission
PM	Performance Measurement
PMS	Performance Measurement Subsystem
Retirement Course	A course that will take the ship out of the weapon danger area, but keep the ship in the general area
R/T	Radio/Telephone
SAC	Scene of Action Commander
SAU	Search Attack Unit
SAUC	Search Attack Unit Commander
Search Area	Boundaries between which sonar search is concentrated
ST	Sonar Technician
SWC	Ship's Weapons Coordinator
TACDEW	Tactical Advanced Combat Direction and Electronic Warfare
TAO	Tactical Action Officer
TDA	Torpedo Danger Area
Time Late	Time required for a SAU to reach datum
TMA	Target Maneuvering Analysis
Track Sup	Track Sup visor, supervises all NTDS detector/trackers

DISTRIBUTION

Commanding Officer
Naval Training Equipment Center
Orlando, FL 32813 75

Defense Technical Information Center
Cameron Station
Alexandria, VA 22310 12

(All others receive one copy)

Commander
USAISD
Attn: Library
Ft. Devens, MA 01433

Mr. Arthur W. Lindberg
US Army Avoinics R&D Activity
DAVAA-E
Ft. Monmouth, NJ 07703

Mr. Donald W. Connolly
Research Psychologist
Federal Aviation Administration
FAA NAFEC ANA-230
Atlantic City, NJ 08405

Dr. Richard S. Vonusa
Rome Air Dev. Center/IRAA
Griffiss Air Force Base
Rome, NY 13441

Dr. Christian Skriver
Naval Air Development Center
Code 6021
Warminster, PA 18974

Commander
Naval Air Development Center
Attn: Code 6022 (G. Holmes)
Warminster, PA 18974

R. Weiner
Naval Air Development Center
Code 4043
Warminster, PA 18974

HQAFSC/DLS
Andrews AFB, DC 20334

Chief of Naval Operations
OP-596C
Washington, DC 20350

Chief of Naval Operations
OP-5948
Washington, DC 20350

Chief of Naval Operations
OP-987H
Attn: Dr. R.G. Smith
Washington, DC 20350

Chief of Naval Material
MAT 08D2
CP5, Room 678
Attn: Arnold I. Rubinstein
Washington, DC 20360

Commander
Naval Air Systems Command
Air 340F
Washington, DC 20361

Dr. Randall Shumaker
Naval Air Systems Command
Code AIR 340E
Washington, DC 20361

Commanding Officer
Naval Air Systems Command
Weapons Training Division
AIR 4135B
Washington, DC 20361

Commander
Naval Sea Systems Command
Code 61R3 (Mr. H.F. Murphy, Jr.)
Washington, DC 20362

Director, Personnel & Training
Analysis Office
Building 200-3
Washington Navy Yard
Washington, DC 20374

Commander
Naval Research Laboratory
Code 5140 (Brier)
Washington, DC 20375

Commander
Naval Air Test Center
CT 176
Patuxent River, MD 20670

Dr. Sam Schiflett
Naval Air Test Center
GY 721
Patuxent River, MD 20670

Mr. Harold C. Glass
US Postal Lab
11711 Parklawn Drive
Rockville, MD 20852

Director, Educational Development
Academic Computing Center
US Naval Academy
Annapolis, MD 21402

Dr. Tice De Young
US Army Engineer Topographic
Laboratories Research Institute
Ft. Belvoir, VA 22060

Dr. Jesse Orlansky
Institute for Defense Analyses
Science and Technology Division
1801 North Beauregard St.
Alexandria, VA 22311

Dr. Henry M. Halff
Office of Naval Research
Code 442
Arlington, VA 22217

Dr. Henry J. Dehaan
US Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

NASA Langley Research Center
Library
Langley AFB, VA 23365

Commanding Officer
FASOTRAGRULANT (50)
NAS
Norfolk, VA 23511

Commander
Naval Air Force
US Atlantic Fleet (Code 312 E)
NAS Norfolk
Norfolk, VA 23511

LSO Training Model Manager
Officer in Charge
LSO Scho 1
Box 171
NAS Cecil Field, FL 32215

Gary Hodak
Training Analysis &
Evaluation Group
Orlando, FL 32813

Commanding Officer
Redstone Scientific Information
Center
US Army Missile Command
Attn: DRSMI-RPR (Documents)
Redstone Arsenal, AL 35809

Chief
ARI Field Unit
P.O. Box 476
Ft. Rucker, AL 36362

Chief of Naval Education
and Training (Code N-948)(R. Kerr)
Pensacola, FL 32508

MAJOR C.A. Denham (LGY)
Air Force Logistics
Management Center
Bldg 205
Sunter AFB, AL 36114

CAPT Vince Mortimer
AFAMRL/BBM
Wright-Patterson AFB
Dayton, OH 45433

Mr. Thomas J. Moore
AFAMRL/BBA
Wright-Patterson AFB
Dayton, OH 45433

Mr. Harold A. Kottmann
ASD/YWE
Wright Patterson AFB, OH 45433

Air Force Human Resources
Laboratory
AFHRL/LR
Logistics Research Division
Wright-Patterson AFB, OH 45433

6570 AMRL/HEC
Wright-Patterson AFB, OH 45433

Chief of Naval Reserve
Code S-3311
New Orleans, LA 70146

Headquarters 34 Tactical Airlift
Training Group/TTDI
Little Rock AFB, AK 72076

Headquarters
Air Training Command, XPTI
Attn: Mr. Goldman
Randolph AFB, TX 78148

US Air Force Human Resources Lab
TS?
Brooks AFB, TX 78235

US Air Force Human Resources Lab
AFHRL-OT (Dr. Rockway)
Williams AFB, AZ 85224

Chief of Naval Education and
Training Liaison Office
Human Resource Laboratory
Flying Training Division
Williams AFB, AZ 85224

AFHRL/OTO
Attn: Dr. Nelson
Luke AFB, AZ 85309

Robert F. Lawson, CDR, USN (RET)
Naval Applications Engineer
ONR Scientific Department
1030 E. Green Street
Pasadena, CA 91106

Commander
Naval Air Force
US Pacific Fleet (Code 342)
NAS North Island
San Diego, CA 92135

Commander
Naval Air Force
US Pacific Fleet (Code 316)
NAS North Island
San Diego, CA 92135

Commanding Officer
Fleet Combat Training Center,
Pacific
Code OOE
San Diego, CA 92147

Commanding Officer
Fleet Anti-Submarine Warfare
Training Center, Pacific
Attn: Code 001
San Diego, CA 92147

John Silva
Naval Ocean Systems Center
Code 823
San Diego, CA 92152

Dr. Robert A. Wisher
Navy Personnel Research and
Development Center
Code P309
San Diego, CA 92152

Navy Personnel Research and
Development Center
Attn: M. McDowell
Library, Code P201L
San Diego, CA 92152

Mr. Warren Lewis
Naval Ocean Systems Center
Human Engineering Branch
Code 8231
San Diego, CA 92152

Commander
Pacific Missile Test Center
Point Mugu, CA 93042

Commander
Naval Weapons Center
Code 3154
Attn: Mr. Bob Curtis
China Lake, CA 93555

Mr. Gary Poock
Naval PG School
Code 55PK
Monterey, CA 93940